ANALYSIS AND IMPROVEMENT OF EXISTING METHODS FOR EVALUATING SPINNABILITY OF FIBER MASSES

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Approved:

Chairman

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CHAPTER I

INTRODUCTION

In recent years increasingly greater emphasis has been placed on the spinning performance of cotton, especially machine picked American cotton. Both foreign and domestic spinners have shown much concern about the poor spinning performance of American cotton even though the cotton appeared to be normal in grade classification. Complaints from spinners suggest that the poor spinning performance of American cotton was caused by changes in technological practices used in the harvesting and ginning segments of the cotton industry. These complaints ignore the technological changes made in the textile industry with regard to larger packages, increased speeds and production rates.

The criterion for evaluating spinning performance is end breakage per 1,000 spindle hours of spinning operation. The procedure used for measuring spinning performance, sometimes called spinning efficiency or ends-down rate, is to spin a nominal yarn size for several thousand spindle hours and record the end breakage during the spinning operation, expressing the end breakage in terms of ends-down per 1,000 spindle hours.

The work of a spinner consists of cleaning, creeling and piecing up broken ends. The proportion of time spent on each of these duties varies widely with the type of yarn being spun. Among the factors affecting a spinner's work load are: staple and grade of the cotton, the count and twist of yarn, the spindle speed, the size of ring, lift and gauge of the frame, the size of roving package in the creel, the type of drafting system, and the presence or absence of air cleaning equipment.

In spite of all these variables, however, it is fairly safe to say that a spinner is primarily engaged in piecing up broken ends. Any alteration of conditions which would result in a reduced end breakage rate would enable the spinner to tend more spindles and produce more yarn for the same number of hours worked.

The purpose of the end breakage test is to develop information on spinning variables on which decisions regarding alterations in these variables can be based. The test can be made to show how the quality of spinning varies with the cotton used, the count, twist, ring, lift, traveller, setting, temperature, humidity and numerous other factors; it does not measure directly either the spinner's duties or work load. From independent observations, the average time required by the spinner to perform each type of operation can be calculated. The end breakage test can be used to calculate work load, since it sets out the frequency of occurrence of each type of end breakage. The statistical techniques (1), as well as other empirical methods employed (2, 3, 4) have demonstrated relationships between fiber properties and yarn properties. However, the lack of a reliable and rapid spinning test has prevented a similar type of analysis with end breakage data.

Spinning encompasses so many variables that, for adequate evaluation for spinning performance, a minimum of 5,000 spindle hours have been traditionally used (5). Limited sample sizes, time available, large number of variables to be evaluated, and the need to determine the simultaneous effect of fiber properties on yarn properties and spinning performance rapidly gave impetus to research to develop accelerated means for measuring end breakage in spinning.

In the paper, "Forecast Ends Down," L. A. Fiori and G. L. Louis of Southern Regional Research Laboratory in New Orleans, Louisiana (6), reported rather compact and efficient test procedure using the findings of previous studies which had been done in this field.

In the following study, the author used the above mentioned test procedure as a basis for further improvements in correcting the ends-down rate for actual yarn count and initial roving bobbin size.

History of the Spinning Test

When ring spinning frames began to replace mule spinning frames, it was generally accepted that when spinning the same count of yarn the ring spindle was capable of producing 50 per cent more yarn per unit time than the mule spindle. However, modernization surveys made at that time contained data which suggested that this superiority of ring frame was not being maintained and in certain instances actual production per man hour, on mules, exceeded that being obtained on the ring frames.

It was realized that if the ring frame was to replace the mule, full advantage would have to be taken of its greater productive capacity. It was, therefore, essential to understand the relative importance of the factors influencing the number of spindles which could be operated by the ring spinner.

James Baines, of England, in his paper which was presented to the conference at Manchester in 1947 (7), divided the ring spinner's work into the following operations: creeling, cleaning and oiling, patroling frames, general supervision, piecing broken ends and the work resulting from end breakages, i.e., removing roller laps, stripping, etc. During the preliminary tests it was observed that the greatest part of the spinner's time was spent piecing up broken ends. Although the manner in which the spinner performed the work affected the rate of end breakages, factors beyond the spinner's control were responsible for the greater portion of the broken ends.

To increase the spinning efficiency some suggestions were made, such as, possibilities of reducing the work of creeling by introducing larger creel packages, reducing the total work by reorganization of cleaning and oiling elements. It was stated that the increases made possible by the above arrangements could however, only be slight, and it had been demonstrated beyond reasonable doubt that the main possibility for increasing spinning efficiency must depend upon maintaining the rate of end breakage below a figure of 30 for one thousand spindle hours of operation.

Another paper presented at the same conference in Manchester by F. Charnely (8), itemized the causes of end breakages. Yarn tension and irregularity was shown to be the main cause of excessive end breakages. Spindle speed, ring and bobbin diameter, traveller weight and ring size were given as principal factors for yarn tension. Roller settings, staple length, yarn twist, quality of carding and mechanical defects were shown as factors which caused yarn irregularity. As miscellaneous causes of end breakage, temperature, humidity, creel, packages, clearer, wastes, and lashes were listed, but the first comprehensive classification of causes of breaks was given by G. U. Steiger (9), who also was the first to devise a practical end breakage test procedure.

The U.S.D.A.* Spinning Laboratory at the University of Tennessee was responsible for the early general evaluation of the spinning performance of new cottons grown in the ARS-Experiment** Station Co-Operative Breeding Program. In many instances a limited amount of stock was available for testing purposes. A method for a spinning test had been developed which required only one-half pound of cotton. Research in several branches of cotton technology were necessary to make the test acceptable. Standard equipment was modified and new small scale machines and specialized testing apparatus were designed and built. When a practical spinning test was worked out, it was necessary to bring the variance in results within allowable limits based upon the precision required by the breeding program.

Small scale spinning test was first developed in England by W. L. Balls and his associates during the period 1920-29 (10). In the U. S., the Agricultural Marketing Service developed a yarn spinning test which used approximately five pounds of lint. Conventional spinning equipment and testing procedures were used. The usual practice in the AMS Laboratories at Clemson, South Carolina and College Station, Texas was to spin two yarn counts in obtaining data for breeders. The initial test developed required only one pound of lint cotton. A special machine was needed to open and clean such a small sample; a miniature opener-cleaner was developed to fill this need. The one pound sample was opened and made into

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*United States Department of Agriculture.

**Agricultural Research Services.

a 14 ounce lap by hand on a special feed tray attached to the card. The 55 grain card sliver produced was drawn twice, using six doublings to each process, to give a finisher drawing sliver of the same weight. The sliver was divided into ten equal parts by weight and made into a 3.25 hank roving. The roving was double creeled for spinning into 22's and 36's yarn. Twenty breaks of standard 120 yard skeins were used to test yarn for strength. Later, a one-half pound spinning test was developed which gave results closely approximating those for the one pound spinning tests. Information on nep count, draw frame settings, roving twists, twist multiplier for maximum skein strength, spinning frame settings, and manufacturing performance could also be obtained from these miniature tests. The manufacturing performance of a sample was an arbitrary rating based on one hundred points for material that gave no roller laps or ends down during processing. Points were subtracted for roller laps and ends down; hence, it would be possible for a cotton to be rated as low as zero. Points were allotted as follows: for roller laps; one lap, 10; two laps, 20; and three or more laps, 50. Points were subtracted for spinning ends down as follows: zero to two, no points subtracted; three or four, 5; five or six, 10; seven or eight, 20; and nine or more, 50. No points were subtracted for low yarn strength grade, or neps because these factors have no bearing on the mill performance of small samples. The object of these experiments was to develop a spinning test that would adequately evaluate new varieties and strains of cotton developed by breeders for yarn strength and at the same time make it economically feasible to test large populations.

A good experimental design is one which provides the required information with the minimum of experimental effort. When conducting an end breakage test on a limited number of spindles, it was realized that without proper interpretation the results obtained could not be directly related to actual mill conditions. Henry K. Woo of North Carolina State College in his paper (11), which was presented at the Cotton Research Clinic of the National Cotton Council of America in February, 1958, made an attempt to translate the end breakage values for a limited number of spindles to those expected for a larger number. Mr. Woo assumed that since the probability of the occurrence of an event is small and the number of occurrences at given time intervals is independent of any other interval, it could be shown that the probability of occurrences in a given time interval follows the Poisson distribution, i.e.,

$$f(x) = e^{-m} \frac{m^x}{x!}$$

where m is the true mean number of occurrences of a random event at a given time interval and x is the number of occurrences of such event.

It was further assumed that practically all the end breakages occur between the nip of the front pair of drafting rolls and the bobbin. If this distance averages 14 inches on a conventional spinning frame with a one inch front roll turning 150 r.p.m.*, there are approximately 20,000 such 14 inch lengths, subject to chances of break each ten spindle hours. Thus in reality, the number of ends down is small; hence the

*revolutions per minute.

probability of occurrence of the number of ends down for a given number of spindles would obey the law of the Poisson distribution. With the use of the Poisson frequency function for a given number of spindles, n, the values of the frequency of occurrence f(x) for various numbers of end-breaks x had been computed and tabulated (Table 1).

Woo states that an end breakage rate as high as 35 breaks per one thousand spindle-hours is considered acceptable by many mills. An end breakage rate between 35 and 75 may be considered to be fair for some work. Spinning performance is considered poor whenever ends down per one thousand spindle-hours exceeds 75, for a test which involves less than 200 spindle hours (Figure 1).

Later a paper from the Kendall Company, Cotton Mills Division Research Laboratories of North Carolina (12), reported that the error associated with spinning end breakage tests of 100 or even 200 spindle hours is so large that the value of a single test of this magnitude had severe limitations. The choice of "acceptable" end breakage rates and the probabilities associated therewith, must be tailored to fit the needs of the mill and test in question. In this respect, limiting a presentation to two arbitrarily selected end breakage rates and a single probability is an undesirable limitation. The first rather complete study of standard deviations of yarn break data was made by E. Fred Schults, Jr., Herschel W. Little, John D. Tallant, and Louis A. Fiori of Southern Regional Research Laboratory, New Orleans, Louisiana (13).

It was observed that standard deviations of yarn break data, taken by uniform increments of spindle hours, increased linearly with average rate of breakage and were larger than expected for a Poisson distribution.

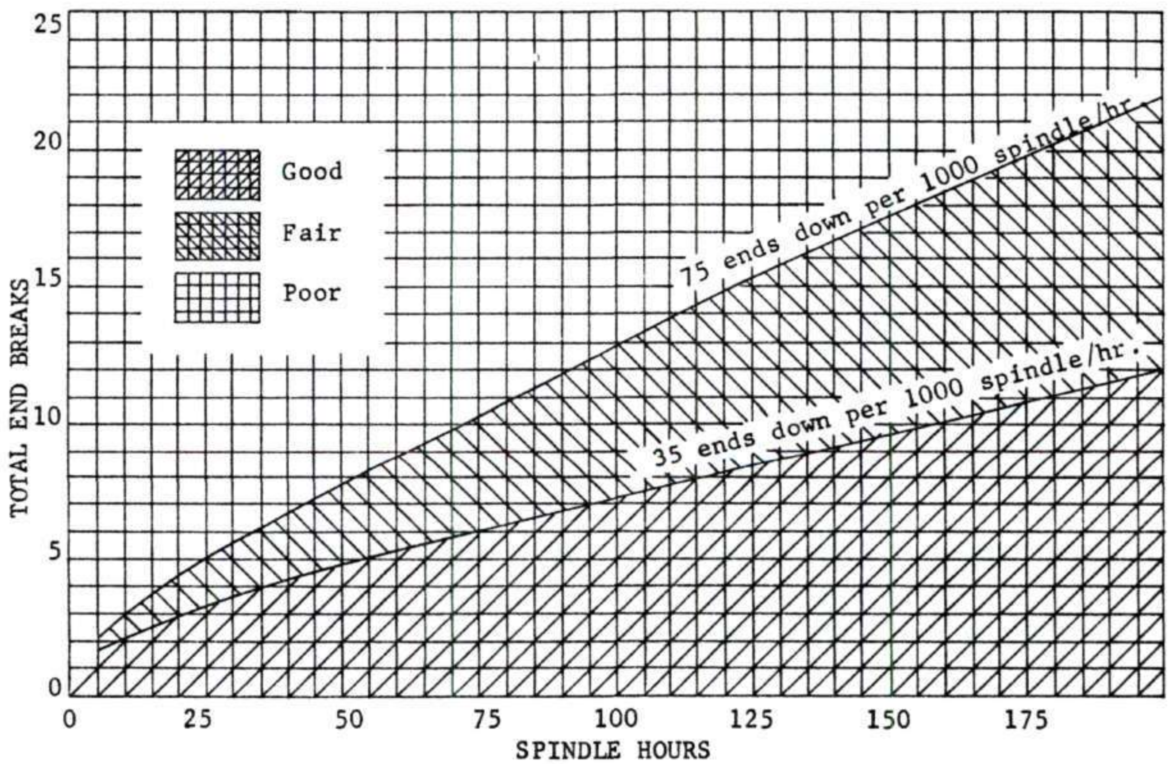

Figure 1. Ends Down Rating Chart, Using Arbitrary End Breaking Levels of 35 and 75 Ends Down per 1000 Spindle Hours

*Source: Henry K. C. Woo, "Predicting Ends Down from Small Lot Spinning Tests", Textile Research Journal, July 1958, p. 614.

Table 1. Frequency of Occurrences of Ends Down
Based on the Poisson Distribution Function

n	5		10		20		30	
Ends Down/1000 sp./hr.	35	75	35	75	35	75	35	75
x								
0	0.84	0.69	0.70	0.47	0.50	0.22	0.35	0.10
1	0.15	0.25	0.25	0.36	0.35	0.34	0.37	0.24
2	0.01	0.05	0.04	0.13	0.12	0.25	0.19	0.27
3		0.01	0.01	0.03	0.03	0.13	0.07	0.20
4				0.01		0.05	0.02	0.11
5						0.01		0.05
6								0.02
7								0.01

n	40		50		60		70	
Ends Down/1000 sp./hr.	35	75	35	75	35	75	35	75
x								
0	0.25	0.05	0.17	0.02	0.12	0.01	0.09	0.01
1	0.35	0.15	0.30	0.09	0.26	0.05	0.21	0.03
2	0.24	0.22	0.27	0.17	0.27	0.11	0.26	0.07
3	0.11	0.22	0.16	0.21	0.19	0.17	0.21	0.13
4	0.04	0.17	0.07	0.19	0.10	0.19	0.13	0.17
5	0.01	0.11	0.02	0.15	0.04	0.17	0.06	0.17
6		0.05	0.01	0.09	0.02	0.13	0.03	0.15
7		0.02		0.05		0.08	0.01	0.12
8		0.01		0.02		0.05		0.08
9				0.01		0.02		0.04
10						0.01		0.02
11						0.01		0.01

n = number of spindles/hr.; x = number of breaks

(continued)

Table 1. (Concluded)

n	80		100		150		200	
Ends Down/1000 sp./hr.	35	75	35	75	35	75	35	75
x								
0	0.06	-	0.03	-	0.01	-	0.00	-
1	0.17	0.02	0.10	0.01	0.03	-	0.01	-
2	0.24	0.04	0.18	0.02	0.07	-	0.02	-
3	0.22	0.09	0.22	0.04	0.13	-	0.05	-
4	0.16	0.14	0.19	0.07	0.17	0.01	0.09	-
5	0.09	0.16	0.13	0.11	0.17	0.02	0.13	-
6	0.04	0.16	0.08	0.14	0.15	0.04	0.15	0.01
7	0.02	0.14	0.04	0.15	0.11	0.06	0.15	0.01
8		0.10	0.02	0.14	0.08	0.08	0.13	0.02
9		0.07	0.01	0.11	0.04	0.10	0.10	0.03
10		0.04		0.08	0.02	0.12	0.07	0.05
11		0.02		0.06	0.01	0.12	0.05	0.07
12		0.01		0.04	0.01	0.11	0.03	0.08
13		0.01		0.02		0.10	0.01	0.10
14				0.01		0.08	0.01	0.10
15						0.06		0.10
16						0.04		0.10
17						0.03		0.08
18						0.02		0.07
19						0.01		0.06
20								0.04
21								0.03
22								0.02
23								0.01
24								0.01
25								0.01

n = number of spindles/hr.; x = number of breaks

Transforming the numbers of breaks to $\log_{10}$ (1 plus number of breaks) stabilized the variance. Seven hundred and twenty spindle hours were found to be sufficient to describe the average number of breaks within 30 per cent of the observed number of breaks with 95 per cent confidence limits. It was from this study that Louis A. Fiori at a later date based his description of a proposed procedure for a complete test to forecast ends down rate. This procedure will be outlined later in this study.

Statement of the Problem

Spinning encompasses many variables. In a pilot plant operation, most of these variables can be made to closely approach actual manufacturing conditions. In order to get a dependable test result, the frequency of end breakage must be corrected for variables which cannot be adequately controlled. These are nominal yarn size and the amount of roving supply on bobbins in the creel. The object of this study was to develop a more effective method for evaluating spinning performance of fiber masses.

In order to eliminate the effect of the size of roving bobbin in the creel it was common practice to creel in the different size roving bobbins at random. This method eliminated the possible effect of size of roving bobbin. It is, however, very difficult to forecast any probable relation between the size of roving bobbin and the breakage frequency; this matter called for careful investigation. If it could be proved that the effect of roving bobbin size is insignificant, then there would be no need to place randomly mixed bobbin sizes in creel.

This would save time for the experimenter and decrease the amount of stock needed for the test. But if the effect was found to be significant then some means for correcting the initial data could be devised, still eliminating the need for creeling different sizes of roving bobbins randomly and saving both effort and amount of stock needed for the test.

This author believed that when both the results of this study and findings of the study made by Samuel T. Burley, Jr. of the U.S.D.A. regarding effect of yarn size on spinning end breakage were combined with the end breakage test procedure devised by Louis A. Fiori (15), the most effective and economical end breakage test method would be achieved.

CHAPTER II

INSTRUMENTATION AND EQUIPMENT

Raw Material Processed

The fiber mass used in the experimental work was prepared by blending two bales of middling, one bale of low middling, and one bale of strict low middling cotton. All of the cottons were grown in Georgia and were classed as one inch staple. The blend was considered to be of a grade and staple quite commonly used in mass production spinning operations. The resulting mixture was considered to be of sufficient quality to insure against excessive end breakage due to low grade cotton.

Additional data on fiber properties can be found in appendix (Tables 11, 12, 13, 14, 15, 16, 17).

Processing Equipment

The following cotton processing equipment was used in this work:

1. A cotton opening line including a Saco-Lowell Opener (1940) and Condenser.
2. Saco-Lowell One-Process Picker and Picker Hopper.
3. Saco-Lowell Card, Metallic Clothing, Equipped with Hollingsworth Granular Carding Plates.
4. Saco-Lowell Drawing Frame, Model DS4, 1957.
5. Whitin Woonsocket Long Draft Roving Frame (Casablancas Drafting System), Moedl G 10, 1939.
6. Saco-Lowell Gwaltney Spinning Frame, Model SJ, 1960.

Physical Testing Equipment

The following physical testing equipment was used for characterization of the experimental products:

1. Shadowgraph, Model 4104-A.
2. Shefield Micronaire, Model D 80400.
3. Spinlab Fibrosampler, Model 192.
4. Spinlab Digital Fibrograph, Model 183.
5. Shirley Analyzer.
6. Ohaus Triple Beam Balance.
7. Saco-Lowell Lap Meter, Model 4, 1951.
8. Uster Evenness Tester Type GGP-B20.
9. Uster Quadratic Integrator, Type ITG-Q7.
10. Uster Automatic Yarn Strength Tester with Automatic Bobbin Attachment.

Table 2. Operational Data for Saco-Lowell Card, Equipped with Hollingsworth Granular Carding Plates

	Type Clothing	Revolutions per Minute
Lickerin	Metallic	498
Pre-opener	Metallic	35
Cylinder	Metallic	180
Doffer	Metallic	9.7

Draft Constant	1580
Draft Gear	15T
Production Constant	0.471
Production Gear	27T

Table 3. Card Settings, in Thousandths of Inch, for Granular Card

Description of Settings		Actual Setting on Card
Feed Plate-Lickerin		12
Pre-opener-Lickerin		10
Pre-opener-Cylinder		7
Lickerin-Cylinder		7
Carding Plates:	Back	15
	Second	7
	Third	7
	Fourth	7
	Front	7
Doffer-Cylinder		7
Mote Knife:	Top	22
	Bottom	17
Mote Knife Angle		15^{o}
Licker Screen:	Front	29
	Bars	12
Cylinder Screen:	Front	$187\frac{1}{2}$
	Middle	58
	Back	29
Back Plate:	Top	17
	Bottom	29
Front Plate:	Top	22
	Bottom	29

Table 4. Operational Data for Saco-Lowell Model DS4 Drawing Frame

	Front Roll	Second Roll	Third Roll	Fourth Roll	Back Roll	Front Draft	Middle Draft	Back Draft
Roll Type:								
Top	Cushion	Cushion		Cushion	Cushion	-	-	-
Bottom	Fluted	Fine Flute	Fluted	Fluted	Fluted	-	-	-
Roll Diameter:								
Top (Inches)	1.125	2.000		1.500	1.500	-	-	-
Bottom	1.125	0.750	1.375	1.375	1.375	-	-	-
Roll Settings:								
Top (Inches)		2.625		1.625	1.875	-	-	-
Bottom		1.063	1.500	1.625	1.875	-	-	-
Draft Range	-	-	-	-	-	2.65-2.83	1.50-3.00	1.23-1.53
Draft	-	-	-	-	-	3.48	. 1.73	1.35
Draft Constant	-	-	-	-	-	175	90	0.059
Draft Gear	-	-	-	-	-	51T	52T	23T

Table 5. Operational Data for Whitin Long Draft Roving Frame

Diameter of Front Roll	1 1/8"
Diameter of Middle Roll	1.05"
Diameter of Back Roll	1.0"
Setting of Front to Middle Roll	2 3/16"
Setting of Middle to Back Roll	2 1/8"
R.P.M. of Main Shaft	367
R.P.M. of Front Roll	212
Number of Spindles	36
Grain Sliver Fed	50 gr.
Hank Roving Delivered	1.00 HR
Actual Twist per Inch	1.2
Draft Constant	264
Draft Gear	44-T
Twist Change Gear	40-T
Twist Constant	50
Production Constant	0.070

Table 6. Operational Data for Saco-Lowell Gwaltney SJ Spinning Frame

Roll Type:			
Front Top	Cushion, 1.125" Diameter		
Middle Top	Apron, 1.125" Diameter		
Back Top	Cushion, 1.063" Diameter		
Front Bottom	Fluted, 1.000" Diameter		
Middle Bottom	Apron, 1.094" Diameter		
Back Bottom	Fluted, 1.000" Diameter		
Roll Setting:			
Front-Middle	1.688 Inches		
Middle-Back	2.000 Inches		
Draft Constant	1026		
Twist Constant	894		
Twist Multiplier	4.5		

	Yarn Number		
	20's	24's	28's
Draft Gear	50	43	36
Twist Gear	44	40	37
Twist per Inch	20	22	24

Table 7. Operational Data for Uster Automatic Yarn Strength Tester

Multiple Bobbin Attachment:	
Type of Bobbin	Quill
Bobbins in Creel	10
Breaks per Bobbin	20
Breaks per Lot of Yarn	200
Knotter Number	1
Continuous Tester:	
Pretension Disc Setting	#5
Length of Jaw Span	20 Inches
Length of Individual Specimen	28 Inches
Setting for Rate of Loading	#6
Loading Time to Break	11 = 1 Seconds
Complete Cycle Time	22 = 1 Seconds
Range of Breaking Load	600 Grams
Range of Elongation	20%
K Value (Breaking Strength)	2.1
e Value (Elongation)	0.4
L Value (Specimen Length)	0.707 Meters

CHAPTER III

PROCEDURE

Preparation of Products

Four bales of one-inch staple upland cotton, ranging in grade from middling to strict low middling were blended in an opening line which included a Saco-Lowell Hopper Feeder, a Superior Cleaner, a Saco-Lowell Opener and a Condenser. Twelve-ounce laps were prepared with a Saco-Lowell One-Process Picker. The picker laps were tested on the Saco-Lowell Lap Meter for average weight per yard, general appearance, and the variation that existed in the yard to yard weight. The mean weight was approximately 12 ounces per linear yard. Lap weight was quite uniform from yard to yard. The weight variation from lap to lap was also found to be very small.

The carding machine used for preparation of sliver was located in the A. French Textile School and was maintained and operated in the same manner as those in industrial plants. Atmospheric conditions were kept constant at 78° F and 55% R.H. during the complete production period. Fifty-grain sliver, produced on Saco-Lowell card equiped with Hollingsworth Granular top and metallic clothing, was drawn on a Saco-Lowell drawing frame to produce a 50-grain drawing sliver. Rovings having a count of 1.0 were produced on Whitin (Woonsocket model) roving frame. Since the same rovings would be used for three different yarn counts the 1.0 hank roving with 1.2 twist per inch was found to be most suitable. The stock cotton was divided into three equal parts and each part was prepared on either full, 2/3 full or 1/3 full roving bobbins. In order to eliminate any new variables in spinning performance, utmost care was taken to prevent damage to the roving bobbin during handling and storage.

Ends Down Test

The Saco-Lowell Gwaltney spinning frame, with 168 spindles, was creeled; an equal number of roving bobbins of each size was distributed randomly over the spindles. The proper randomization was achieved by first numbering each spindle from 1 to 168 then assigning the roving bobbin size by the use of a table random numbers. The number given to each spindle was written on the ring rail to identify each spindle which was used in the end breakage test. The randomization in the creel was done to eliminate the effect of position.

The spinning frame was run for one doff period without taking any data to break-in the rings, and assure that faulty rings would not present any effect on the data. Since yarn tension is one of the major factors controlling the end-breakage rate it was kept constant for each yarn size spun. It was assumed that there is direct relationship between density of yarn bobbin and yarn tension. Thus to keep the yarn tension constant during spinning, traveller weights which would produce yarn bobbins with the same density were used. Travellers to be used were determined from a graph prepared by Fiori (16), by plotting yarn size and spindle speeds (Figure 2).

The Saco-Lowell Gwaltney spinning frame used in this investigation was located in an A. French Textile School laboratory where the atmospheric

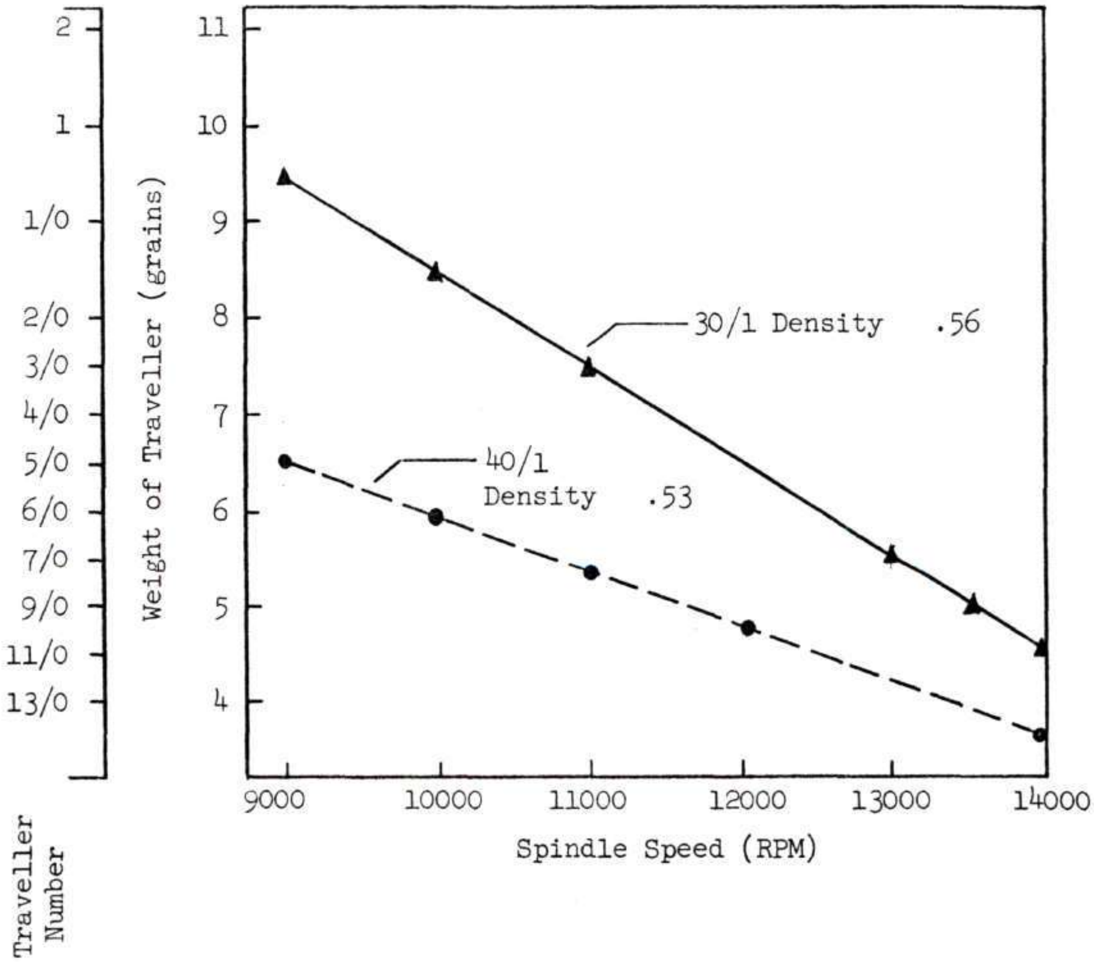

Figure 2. Relation Between Traveller Weight and Spindle Speed to Maintain Constant Yarn Tension.*

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*Source: L. A. Fiori and G. L. Louis, "Forecast Ends Down", Textile Industries, October 1963, p.68.

conditions were kept constant at 70° F and 55% RH throughout the entire time of the test. The spindle speed of 9000 was held constant for spinning each yarn size to assure that variable spindle speeds would not introduce a new variable to the ends-down rate.

The test was conducted in accordance with the procedure devised by G. L. Louis and L. A. Fiori. Small changes in the procedure had to be made to adapt it for this study. Test steps can be listed as follows:

1. When initiating the test end breakage criteria were used to establish the proper spindle speed. Tabulated end breakage criteria are given on Table 8.

2. 20's, 24's, 28's yarn counts were arbitrarily chosen and two complete doff periods were run for each yarn count.

3. Broken ends immediately following each doff were pieced-up and were not recorded. After the operation had stabilized the frame was patroled, broken ends were pieced-up continuously and recorded by spindle number; roving bobbin size was noted and recorded. The causes of end breakage were grouped under seven different categories. Each broken end was examined and if there was an assignable cause it was recorded accordingly. The causes were listed as lashes, roving breaks, traveller off, hard end, thin place, roller lap, and if there was no evidence that breakage could be assigned to any one of these causes it was simply marked, break.

4. Data were grouped and totaled at 15 minute intervals. For comparative analysis the data for 17 intervals after the fourth interval was totaled. The total of 17 intervals approximates 720 spindle-hours which had been reported to be a minimum number of spindle hours to be observed for statistically sound results.

Explanation of assignable causes of breaks are as follows:

Table 8. Control Chart Limits

Spinning Period	Spinning Time in Minutes	Lower Limit of End Breakage*	Upper Limit of End Breakage**
1st	15	-	35 with at least 13 occurring in the second period
2nd	30	-	
3rd	45	0	47
4th	60	0	59
5th	75	1	71
6th	90	1	83

*If end breakage rate is within these limits at the end of 90 minutes of spinning the test can be stopped.

**If the end breakage rate is outside these limits at the end of 30 minutes or any subsequent 15-minute interval, the test should be stopped, the spindle speed should be reduced 500 or 1000 rpm., and a new set of tests should be made with these reduced spindle speeds.

Lashes: These are ends brought down by adjacent balloons lashing into one another, or by the free end of broken yarn lashing into other ends. In either case the cause of the trouble can usually be spotted by the observer, but if in doubt, a group of ends down together is generally classified as "lashed down".

Roving breaks: These are "ends-down" caused by a roving breaking back in the creel.

Traveller off: These are "ends-down" caused by travellers breaking and flying off.

Hard end: Hard ends are lengths of roving which have passed through the rollers without being drafted; they usually balloon excessively and are caught on the tails of the thread guides, forming snarls which are sometimes transferred to the bobbins but most of the times they result in an end break.

Thin place: If the examination of broken end reveals that it is excessively fine, and so weak as to pull apart like roving instead of breaking with the snap characteristic of yarn, then the break is classified as thin place.

Roller lap: Roller laps are caused by improperly functioning clearers. Laps can be formed on both top and bottom rolls. Ends down caused by roller laps are classified under this heading and recorded separately.

Breaks: Breaks which do not fall into any of the above categories are classed under the heading of breaks. This is always the largest class.

Tests for Breaking Strength and Elongation of Yarn

The Uster Automatic Yarn Tester was used to test the breaking strength as well as the elongation of the yarn. This tester makes use of the inclined plane principle of loading in which the pull on the specimen under test increases proportionately with time. It can be set to give an automatic pretensioning of the sample before the load is applied. The unique feature of this tester, along with being automatic, was the consistency of the handling technique employed. Each specimen tested always possessed the same amount of pretension, force on the jaws, and twist alteration. Twenty breaks were made from each of the ten bobbins giving 200 breaks per lot of yarn.

The breaking strength and elongation for each individual test were recorded on an autograph. The breaking strength was recorded on the top part while the elongation was recorded on the lower half. Two counters, one for breaking strength and one for the elongation, kept a cumulative sum of the data. At the end of the test, the data from the counters were used to obtain the mean values. Individual readings from the autograph were tabulated and their average value and standard deviations were found by making use of an electronic computer.

The frequency distribution of the breaking strength was also obtained from the machine. At the end of each individual test a small ball was dropped into the proper vertical slot in a plate corresponding to its breaking strength. At the end of a test series, the frequency distribution diagram formed by these balls in their respective slots was transferred to a ruled chart as a permanent record.

Tests for Evenness

The evenness tests were conducted with a Uster Evenness Tester and its auxiliary equipment. The evenness tests were conducted in the following manner. The integrator was cleared for 30 seconds to remove any data that might have been stored in the memory from past tests. By movement of a lever the memory of the integrator was activated to permit storage of the data from the product being drawn through the measuring comb. The memory had one minute capacity and the first reading was obtained one minute after memory activation. The readings were obtained every half minute thereafter until the total numbered five. Essentially this constituted the complete test.

The card sliver was first to be tested followed by the drawing sliver. The tests were performed at 25 yards per minute, using measuring comb slot number 3, which has a sensitivity range of 25 per cent.

Roving evenness tests were conducted at 50 yards per minute at sensitivity range of 50 per cent, and in measuring comb slot number six. The yarn evenness tests were conducted at 100 yards per minute a sensitivity range of 100 per cent, and in measuring comb slot number six.

The reading obtained from the quadratic integrator was the standard deviation of the product diameter expressed as a per cent of the average or per cent coefficient of variation (% C.V.) as it is most commonly known.

CHAPTER IV

DISCUSSION OF RESULTS

Before discussing the results of this particular investigation it may be worthwhile to present, briefly, the several factors which influence the end breakage rate, such as spindle speed, position of yarn on the bobbin, twist, yarn tension, and draft. Effects of these factors were investigated together and separately in several studies previously made. The findings of these investigations may be summarized as follows:

Effect of spindle speed: Several authors have shown that increases in spindle speed resulted in an increased rate of end breakage. Rate of increase in end breakage due to increased spindle speed is more pronounced for speeds beyond 11000 rpm. This is clearly seen on Figure 4.

Effect of yarn position on bobbin: Figure 3 shows the typical pattern of how end breakages are related to different positions on a spinning bobbin. The data for the figure were taken from the test of 28's yarn in this study. End breakage rate is usually higher at the beginning of the yarn package, as the yarn starts to wind on the bottom portion of the bobbin. Gradually the end breakage declines and levels off after the tapered portion of the bobbin is built up, and remains relatively constant until the upper tapered portion begins to build. Then, the rate of end breakage increases significantly and usually exceeds the level at the beginning of the bobbin. Since one of the objectives of de-

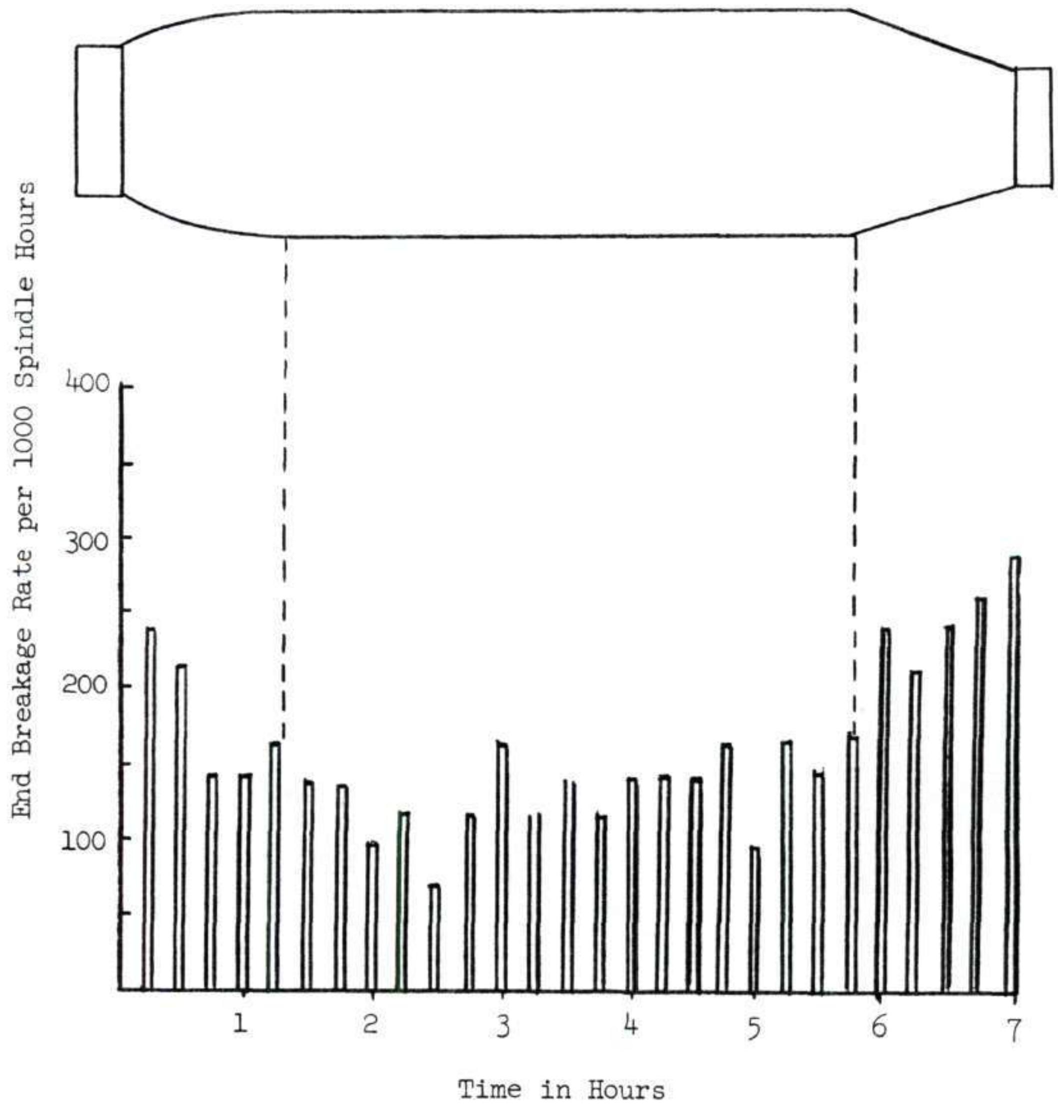

Figure 3. Rate of End Breakage Change from an Empty to Full Bobbin

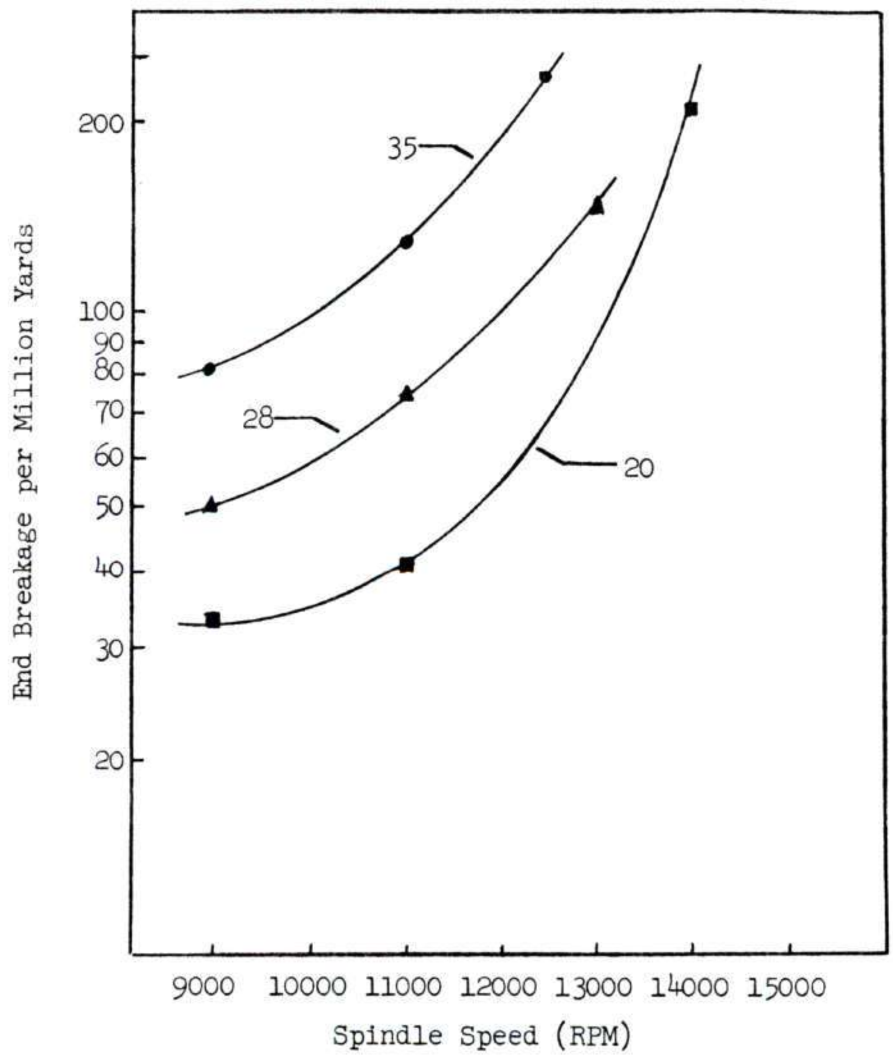

Figure 4. The Effect of Spinning Draft on End Breakage*

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*Source: L. A. Fiori and G. Louis, "Forecast Ends Down", Textile Industries, October 1963, p.70.

veloping laboratory testing procedures is to evaluate the spinning performance of fiber masses rather than the machines, it would appear desireable to run the test at the midsection of the bobbin where the rate of end breakage variability is most stable.

Fiori and Louis have discussed the relationships between twist, spindle speed, and end breakage rate for a given cotton (17). Their findings are illustrated in Figure 5. For the 4.25 T.M. the end breakage curve is relatively stationary in the range of spindle speeds illustrated, indicating that the rate of end breakage increase is small as spindle speed is increased. On the other hand, for 3.75 T.M. the rate of end breakage increase is rapid and approaches a non-spinnable limit at about 12,500 rpm. This indicates that when using the same traveller weight and yarn size at each level of spindle speed, low twist yarns can be expected to have greater end breakage rates at high spindle speeds when compared with high twist yarns.

The interactions of strength, elongation, and density of yarn bobbin on end breakage are difficult if not impossible to distinguish or separate so that the effects of yarn tension on end breakage could be studied individually. However, previous studies have resulted in positive indications that any increase in yarn tension would result in increased rate of end breakages (18).

Figure 4 shows the effect of increases in spinning draft and spindle speed on end breakage rate found by Fiori and Louis (19). The curves represent three 40's yarn spun from three sizes of roving (2.00, 1.43, and 1.14 hanks for 20, 28, and 35 drafts respectively). Increasing the draft causes appreciable increases in end breakage, regardless of the

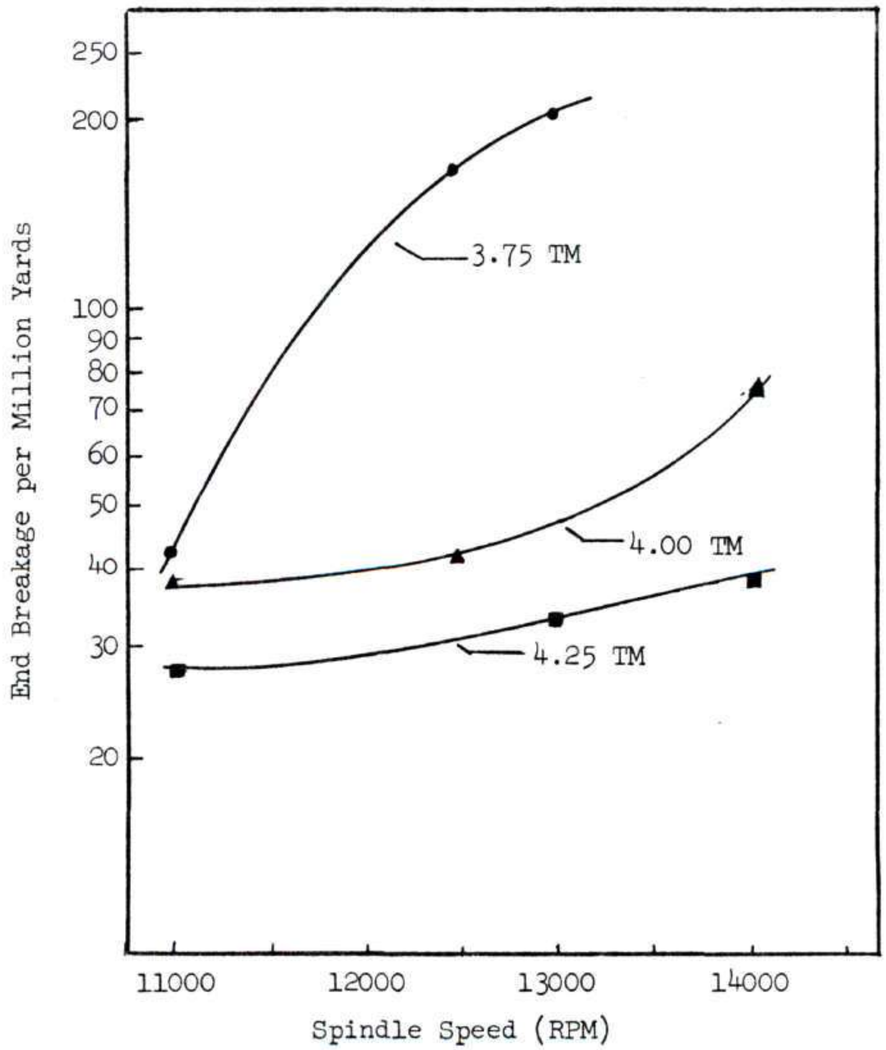

Figure 5. The Effect of Yarn Twist on End Breakage Rate*

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*Source: L. A. Fiori and G. Louis, "Forecast Ends Down", <u>Textile Industries</u>, October 1963, p.69.

level of spindle speed. The effect of draft is, however, more significant at low spindle speeds.

John D. Tallant, and Louis A. Fiori reported that the findings on the interrelation between short fiber content and spinning efficiency show an extremely complex pattern due to the strong interactions of processing variables such as spinning tension, spindle speed, and yarn size (20). However, there were strong indications that increases in short fiber content result in increased difficulty in spinning at medium yarn counts and low twists.

Textile processing equipment is designed to spin a nominal, not an exact, yarn size. Cottons of different characteristics respond differently to the actions of the equipment, varying the yarn count produced with identical equipment and under identical atmospheric conditions. Thus when comparing two different cottons or two different processing methods on the same stock and if there is noticeable difference between exact yarn count and nominal yarn count observed; end breakage rates should be corrected to exact yarn count. Samuel T. Burley Jr. of the U.S.D.A. reports that the three part formula given below covers the largest range of variation possible (21). The three-phase correction formula: I. correction for difference from desired yarn size; II. correction for level of ends-down (60-145); and III. correction for heavier than nominal yarn count and level of ends-down (when heavier than one yarn count and observed ends-down greater than fifty).

$$\text{I.}\quad E_{c_1} = E_o \left[.15(S_d - S_o) + 1.00 \right]$$

$$\text{II.} \quad E_{c_2} = E_o \frac{\sqrt{(E_o - 60)3.0}}{100}$$

$$\text{III.} \quad E_{c_3} = E_o \left[\frac{(7.5\left[S_d - S_o - 1\right])^2}{100} \right]$$

where: E_{c_1}, E_{c_2}, E_{c_3} = Corrected ends-down rate for phases one, two, and three.

E_o = Observed ends-down rate.

S_d = Desired yarn count

S_o = Observed yarn count

After spinning a cotton, the ends-down rate and average yarn count values would indicate what part or parts of this formula is to be used. Average observed yarn counts in this study were 19.9's, 23.8's, and 27.7's for 20's, 24's, and 28's desired yarn counts. If there were two different stocks to be compared on the level of 28's yarn it would then be necessary to employ the third phase of the above correction formula.

The end breakage rate will increase with yarn count increase when all factors are held constant. Figure 6 was prepared by plotting total end breakages for three levels of yarn count used in this investigation. It is rather interesting to note that total end breakages for 24's cotton yarn is lower than both 20's and 28's yarn for 1/3 full, and full bobbins. This behavior indicates a nonlinear relationship between yarn size and end breakage rate for these sizes. Since the repeatability of test results within each level of yarn count was very good, this behavior could not be attributed to experimental error. A summary of the test re-

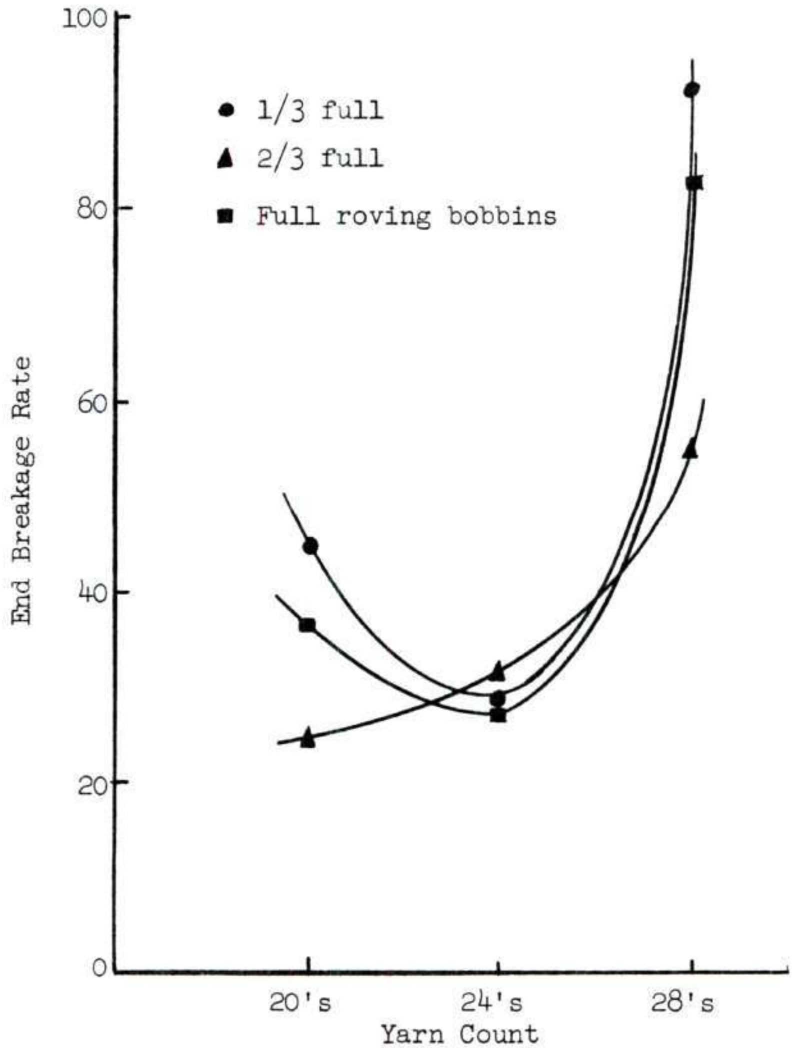

Figure 6. The Effect of Yarn Count on End Breakage Rate

sults is given in Table 9. An analysis of variance of these data shows that yarn count is the main source of variation. The effect of both linear and quadratic components of yarn count is significant at the one per cent level. Figure 6 indicates a significant quadratic effect for the 1/3 full and full bobbins while the 2/3 full bobbins show a linear increase in ends down rate with yarn count.

In order to investigate the effect of initial roving bobbin size an analysis of variance table was prepared for two factors with three levels and two replications on each level (Table 10). The factors are initial roving bobbin size and yarn count. The F ratio for interaction between the two factors is less than one. This suggests that there is no significant interaction. To obtain more degrees of freedom for the error term the interaction and the replication terms are pooled, giving thirteen degrees of freedom. The F ratio for the effect of initial roving bobbin size is found to be 2.17. An F ratio this large or larger would be expected approximately 17 per cent of the time if there were no effect due to change in bobbin size. When the variation caused by roving bobbin size is separated into linear and quadratic components, it is found that while the linear component is not significant the quadratic component is significant at the 7% level.

These experimental data suggest that there is no basis to reject the hypothesis which says, the initial roving bobbin size has no effect on end breakage rate. The data indicate a significant quadratic effect. This effect can be seen in Figure 7 where the ends down rate is observed to be different for bobbins which are 2/3 full than those which are either 1/3 full or full.

Table 9. Summary of Seven-hundred-twenty-hour End Breakage Test

Yarn Count	Test Number	Initial Roving Bobbin Size 1/3 Full	2/3 Full	Full	Total
20's	1	20	13	18	104
	2	24	11	18	
24's	1	15	17	11	87
	2	13	14	17	
28's	1	61	23	37	229
	2	31	31	46	
Total		164	109	147	

Table 10. Analysis of Variance Table for End Breakage Test Data

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Square	Variance Ratio	Significance Level
Yarn Count (Y)					
Linear Y	1302.08	1	1302.08	21.42	Less than 1%
Quadratic Y	702.25	1	702.25	11.55	Less than 1%
Total	2004.33	2	1002.17	16.45	Less than 1%
Bobbin Size (B)					
Linear B	24.08	1	24.08	0.39	Not significant
Quadratic B	240.25	1	240.25	3.94	At 7%
Total	264.33	2	132.17	2.17	At 17%
Interaction (Y x B)					
Lin. Y x Lin. B	0.13	1	0.13	0.02	Not significant
Lin. Y x Quad. B	51.04	1	51.04	0.83	Not significant
Quad. Y x Lin. B	12.04	1	12.04	0.19	Not significant
Quad. Y x Quad. B	171.13	1	171.13	2.76	At 14%
Total	234.34	4	58.59	0.95	Not Significant
		13		60.87	
Replication R(Y x B)	557.00	9	61.89		
Total	3060.00	17			

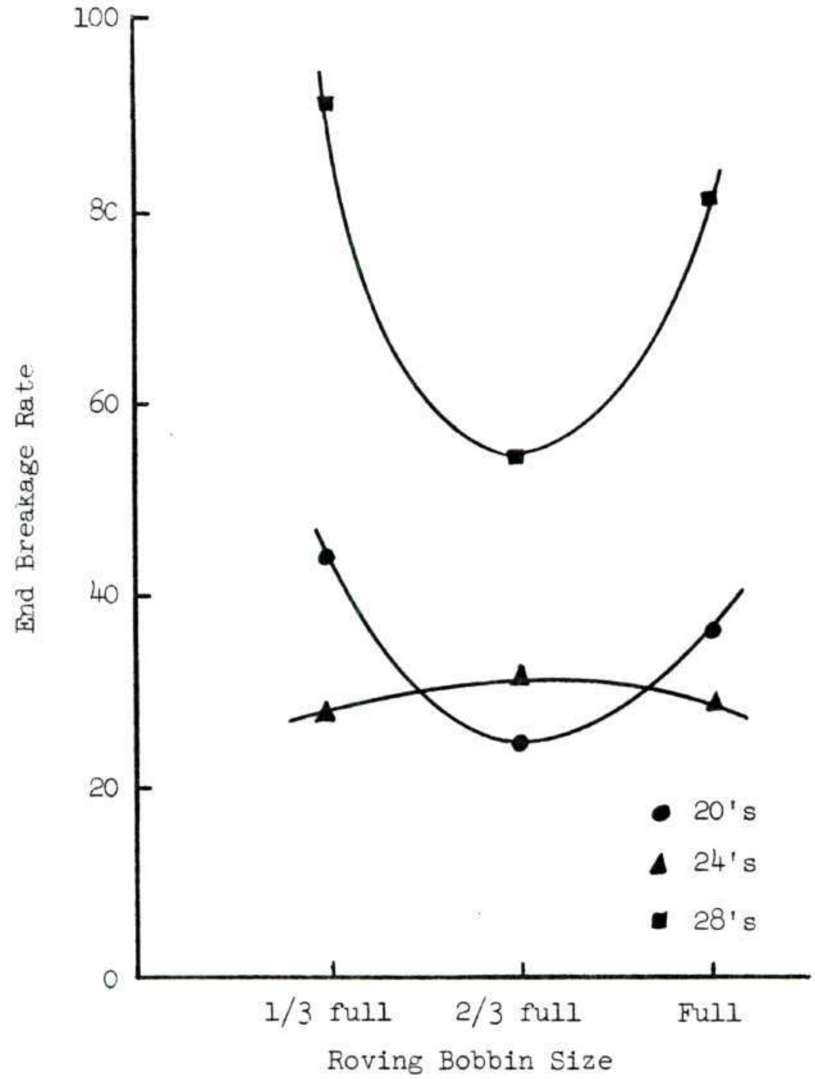

Figure 7. The Effect of Bobbin Size on the End Breakage Rate

CHAPTER V

CONCLUSIONS

The conclusions reached from the statistical interpretation of the data, taken during this investigation, and careful study of previous works on end breakage rate are as follows:

1. The spinning end breakage test is promising and reliable for evaluating the effects of properties and processing variables on spinning performance of fiber masses.

2. The repeatability of end breakage tests is very good provided that processing machinery is maintained in good working condition.

3. The yarn size has a significant effect on end breakage rate. The relationship between end breakage rate and yarn size due to interactions with other variables in spinning cannot always be established; however, for finer yarn counts the end breakage rate will be greater.

4. Since textile processing equipment is designed to spin a nominal yarn count rather than exact yarn count, results of end breakage tests should be corrected for the desired yarn count. The correction formula is given in terms of corrected ends down, observed ends down, desired yarn size, and observed yarn size (22).

5. Initially full and only 1/3 full roving bobbins seem to have greater end breakage rate when compared to 2/3 full roving bobbins. Analysis of variance of the data indicate that there is no basis to reject the hypothesis that the roving bobbin size has no effect on end

breakage rate. The linear component of the variation due to roving bobbin size is not significant, but the quadratic component of the variation is significant at approximately the 7 per cent level. Further experimentation is needed to establish the true relationship between end breakage rate and initial roving bobbin size.

CHAPTER VI

RECOMMENDATIONS

It is recommended that to assure the validity of findings of this study and previous investigations for fiber masses other than cotton, similar investigations should be made using popular cotton mixes and 100 per cent man made fibers. An investigation of this type should cover the most important factors which affect the end breakage rate in spinning. The seven-hundred-twenty-hour spinning test devised by L. A. Fiori and G. L. Louis should be usable for obtaining statistically sound results.

Further experiments should be made to determine the effect of roving bobbin size on end breakage rate, so that alterations in experimental design can be made to save both effort and stock used during end breakage test. Future experiments should test the effect of roving bobbin size on levels different from those used in this investigation. Recommended levels are 1/6, 1/3, 1/2, 2/3, 5/6, and full roving bobbins. These further tests will give a better indication of the form of the relationship between ends down rate and bobbin size.

APPENDIX

Table 11. Shirley Analysis of Trash Content in Bale Number 1, Middling Georgia Cotton.

Test Number	Weight of Sample	Weight of Trash Collected	Weight of Lint Collected	Per Cent Trash in Sample	Per Cent Lint in Sample	Per Cent Cage Loss
1	100	1.4	97.3	1.4	98.3	0.3
2	100	1.4	97.4	1.4	98.4	0.2
3	100	1.6	97.0	1.6	98.0	0.4
4	100	1.5	97.3	1.5	98.3	0.2
5	100	1.2	97.4	1.2	98.4	0.4
Total	500	7.1	486.4	7.1	491.4	7.1
Average	100	1.42	97.28	1.42	98.28	1.42

Table 12. Shirley Analysis of Trash Content in Bale Number 2, Middling Georgia Cotton.

Test Number	Weight of Sample	Weight of Trash Collected	Weight of Lint Collected	Per Cent Trash in Sample	Per Cent Lint in Sample	Per Cent Cage Loss
1	100	1.7	97.2	1.7	98.2	0.1
2	100	1.5	97.1	1.5	98.1	0.4
3	100	1.4	97.4	1.4	98.4	0.2
4	100	1.6	97.2	1.6	98.2	0.2
5	100	1.5	97.5	1.5	98.5	0.0
Total	500	7.7	486.4	7.7	491.4	0.9
Average	100	1.54	97.28	1.54	98.28	0.18

Table 13. Shirley Analysis of Trash Content in Bale Number 3, Low Middling Cotton.

Test Number	Weight of Sample	Weight of Trash Collected	Weight of Lint Collected	Per Cent Trash in Sample	Per Cent Lint in Sample	Per Cent Cage Loss
1	100	1.5	97.2	1.5	98.2	0.3
2	100	1.6	97.3	1.6	98.3	0.1
3	100	1.3	97.4	1.3	98.4	0.3
4	100	1.0	97.9	1.0	98.9	0.1
5	100	1.4	97.5	1.4	98.5	0.1
Total	500	6.8	487.3	6.8	492.3	0.7
Average	100	1.36	97.46	1.36	98.46	0.14

Table 14. Shirley Analysis of Trash Content in Bale Number 4, Strict Low Middling Cotton.

Test Number	Weight of Sample	Weight of Trash Collected	Weight of Lint Collected	Per Cent Trash in Sample	Per Cent Lint in Sample	Per Cent Cage Loss
1	100	2.6	96.4	2.6	97.4	0.0
2	100	2.5	96.4	2.5	97.4	0.1
3	100	2.8	95.9	2.8	96.9	0.3
4	100	2.7	95.9	2.7	96.9	0.4
5	100	2.5	96.1	2.5	97.1	0.4
Total	500	13.1	480.7	13.1	485.7	1.1
Average	100	2.62	96.14	2.62	97.14	0.22

Table 15. Shirley Analysis of Trash Content in Picker Lap

Test Number	Weight of Sample	Weight of Trash Collected	Weight of Lint Collected	Per Cent Trash in Sample	Per Cent Lint in Sample	Per Cent Cage Loss
1	100	0.6	98.2	0.6	99.2	0.2
2	100	0.7	98.1	0.7	99.1	0.2
3	100	0.7	98.0	0.7	99.0	0.3
4	100	0.5	98.4	0.5	99.4	0.1
5	100	0.4	98.6	0.4	99.6	0.0
Total	500	3.1	491.3	3.1	496.3	0.8
Average	100	0.62	98.26	0.62	99.26	0.16

Table 16. Fiber Fineness Expressed in Micrograms Per Inch

Test Number	Micronaire Value Bale Number*	1	2	3	4
1		4.6	4.8	4.2	5.2
2		4.8	4.7	4.3	5.3
3		4.7	4.8	4.4	5.1
4		4.6	4.6	4.2	5.0
5		4.6	4.7	4.2	5.0
6		4.7	4.8	4.2	5.1
7		4.6	4.6	4.2	4.9
8		4.8	4.6	4.3	5.3
9		4.7	4.6	4.2	5.0
10		4.7	4.8	4.2	5.6
11		4.7	4.7	4.6	4.9
12		5.0	4.8	4.2	5.1
13		4.8	4.7	4.1	5.3
14		4.7	4.7	4.3	5.0
15		4.7	4.9	4.2	5.0
16		4.7	4.9	4.3	4.8
17		4.6	4.9	4.3	4.9
18		4.7	5.0	4.3	5.0
19		4.6	4.7	4.2	5.0
20		4.8	4.7	4.4	4.9
Total		94.1	95.0	85.3	101.1
Mean		4.7	4.8	4.3	5.1

*Bales #1 and #2, Middling Georgia Cotton
Bale #3, Low Middling Cotton
Bale #4, Strict Low Middling Cotton

Table 17. Fiber Length Analysis Using the Digital Fibrograph Four Bale Blend

Test Number	Span Length 66.7%	50.0%	*2.5%	Uniformity Ratio %	Secant Mean	Floating Fiber %
1	0.353	0.463	0.901	51.39	0.759	18.70
2	0.353	0.455	0.909	50.01	0.759	19.76
3	0.324	0.427	0.917	46.56	0.672	36.46
4	0.326	0.425	0.877	48.46	0.678	29.35
5	0.336	0.441	0.923	47.78	0.708	30.37
6	0.322	0.427	0.902	47.34	0.666	35.44
7	0.330	0.439	0.903	48.62	0.690	30.87
8	0.362	0.462	0.903	51.16	0.786	14.89
9	0.324	0.428	0.917	46.67	0.672	36.46
10	0.330	0.438	0.904	48.45	0.690	31.01
Mean	0.336	0.441	0.906	48.64	0.708	28.33

*Classers Length

$$\text{Uniformity Ratio} = \frac{50\%\ \text{Span Length}}{2.5\%\ \text{Span Length}} \times 100$$

$$\%\ \text{Floating Fiber} = \frac{2.5\%\ \text{Span Length}}{\text{Secant Mean}} - 1 \times 100$$

$$\text{Secant Mean} = 3(66.7\%\ \text{Span Length} - 0.1)$$

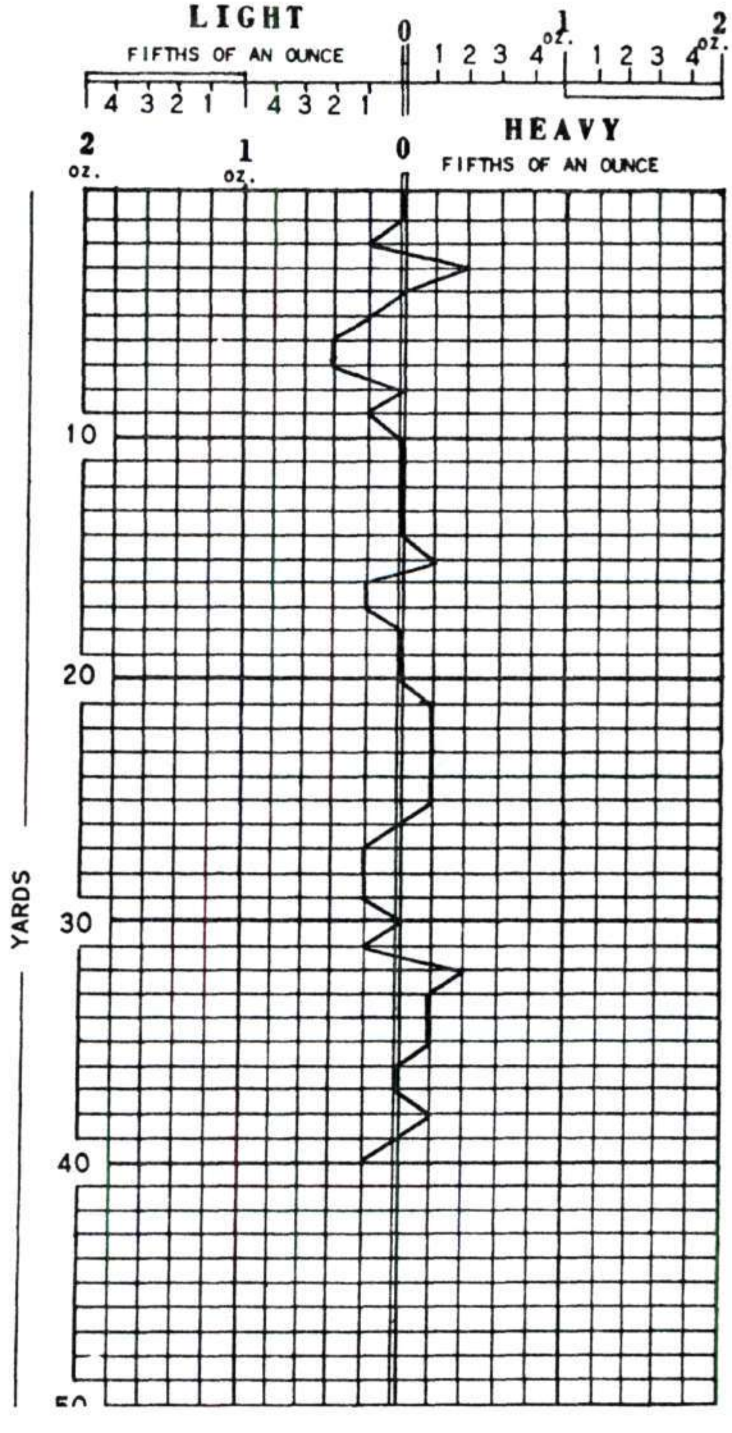

Figure 8. Saco-Lowell Lap Meter Record

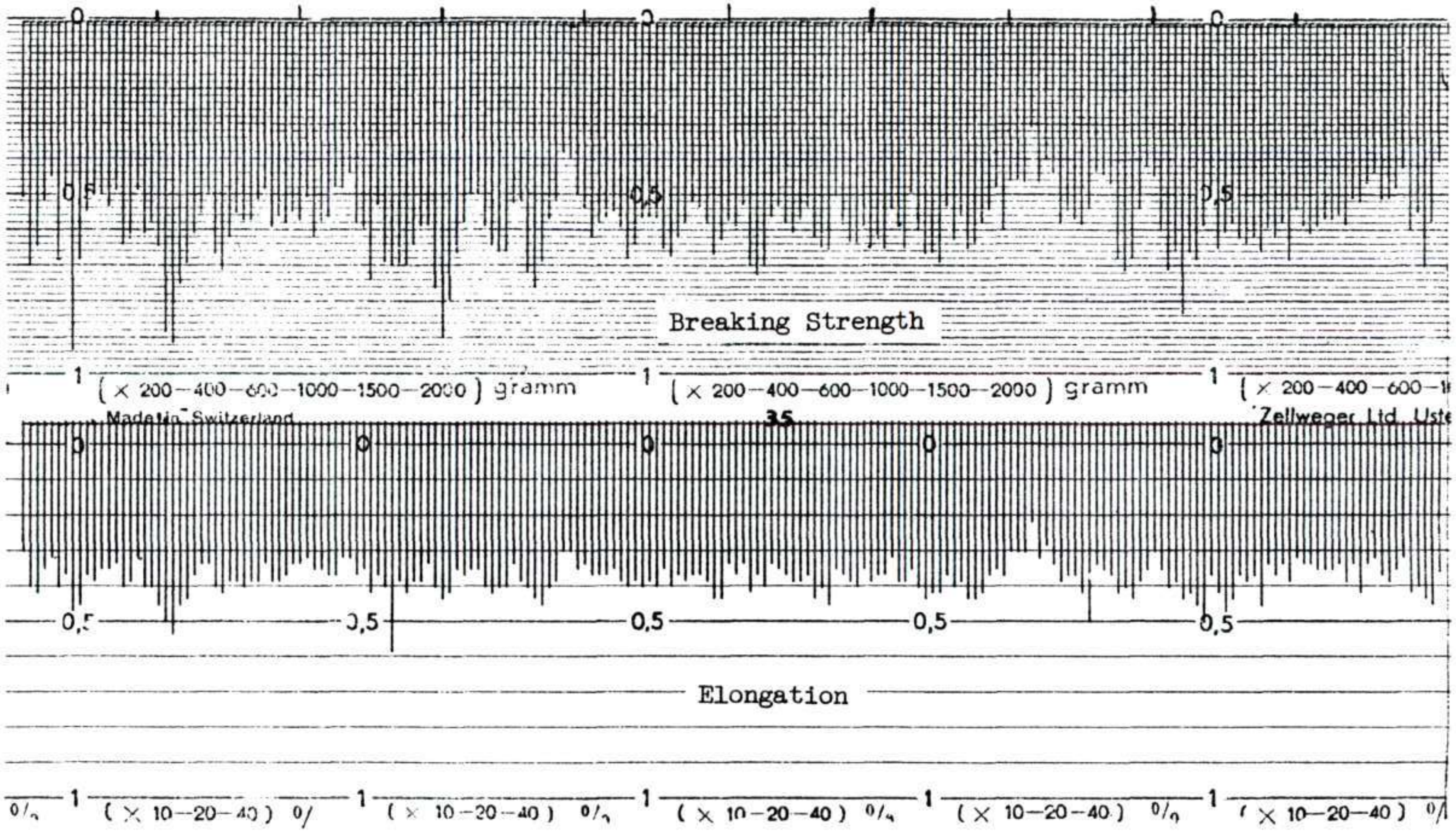

Figure 9. Breaking Strength and Elongation
Autograph for 20's Yarn

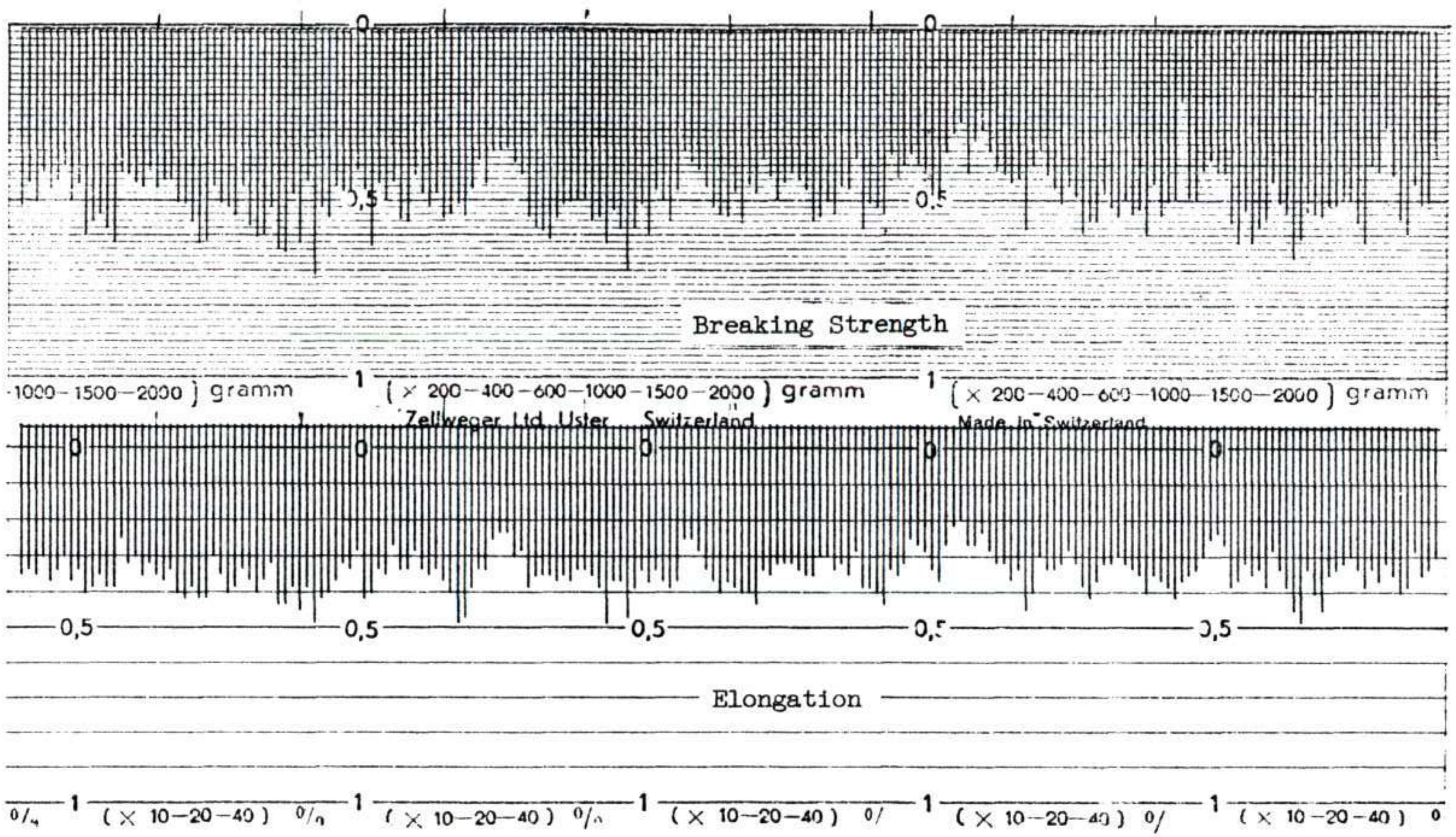

Figure 10. Breaking Strength and Elongation
Autograph for 24's Yarn

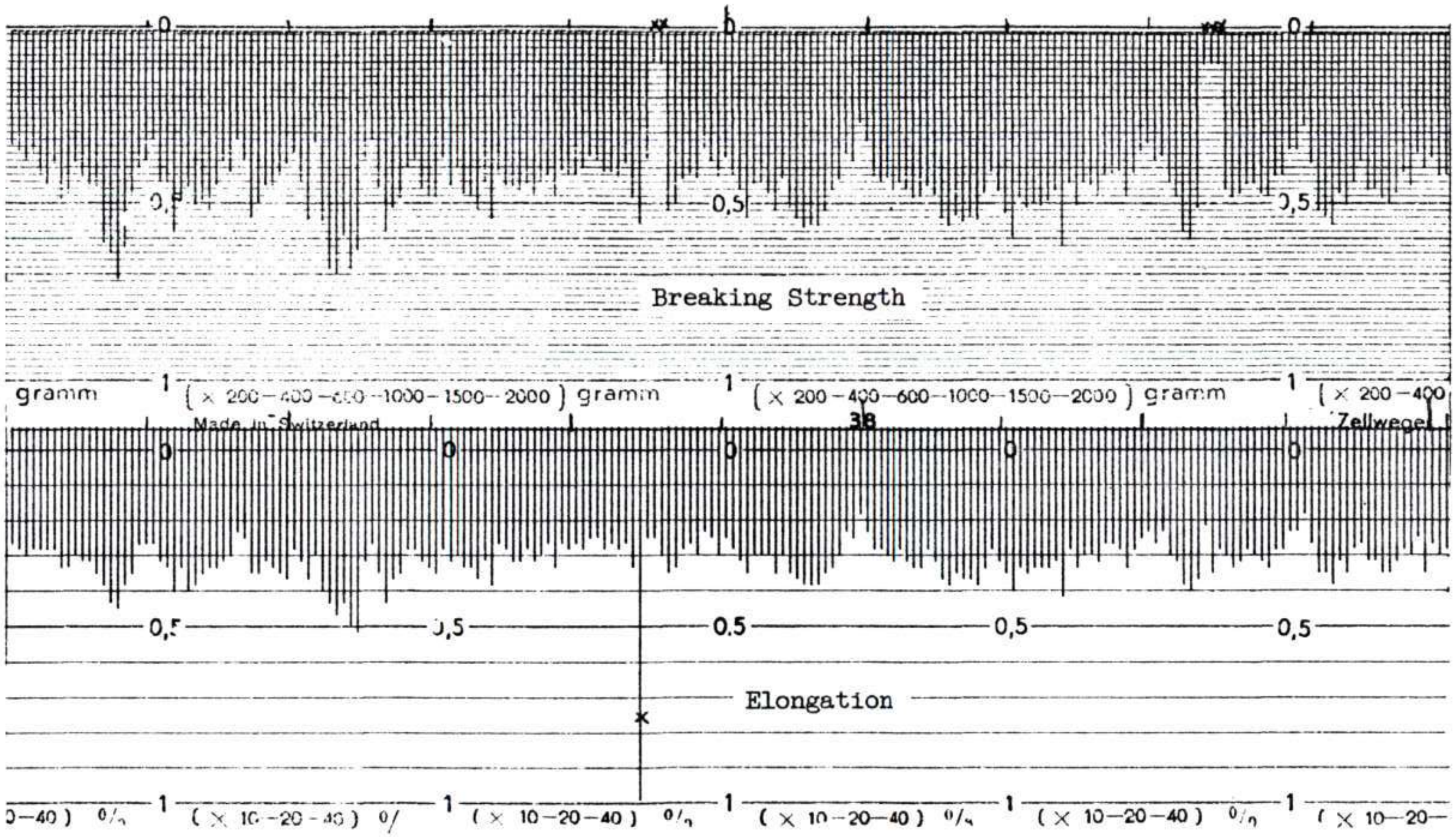

Figure 11. Breaking Strength and Elongation Autograph for 28's Yarn

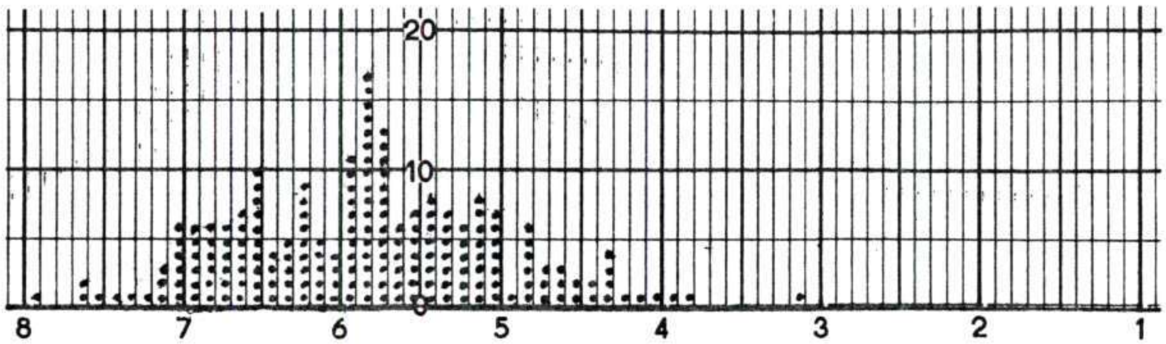

Figure 12. Frequency Distribution of Yarn Breaking Strength for 20's Yarn

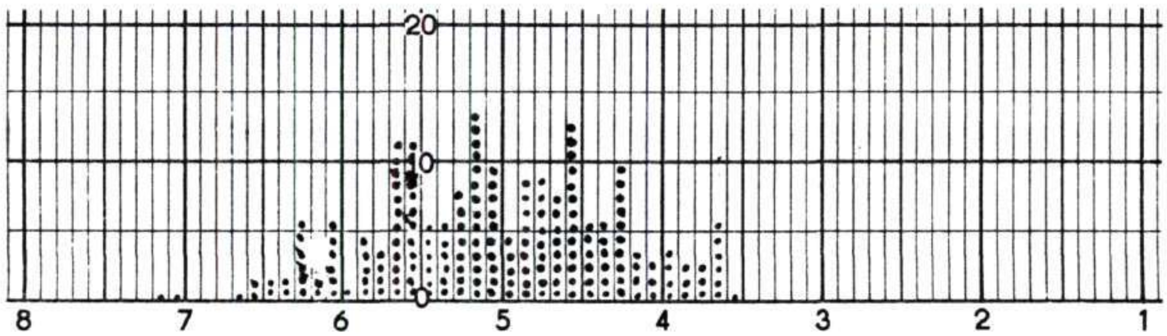

Figure 13. Frequency Distribution of Yarn Breaking Strength for 24's Yarn

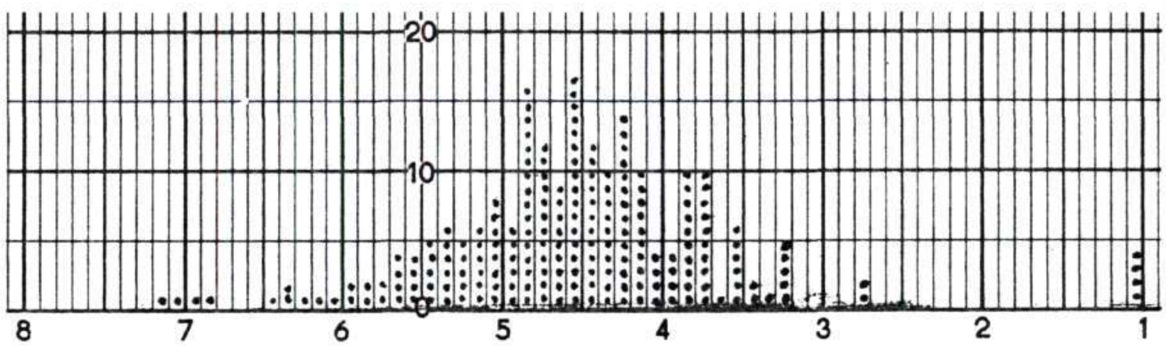

Figure 14. Frequency Distribution of Yarn Breaking Strength for 28's Yarn

Table 18. Breaking Strength in Grams From Autograph for 20's Cotton Yarn

Break Number	Bobbin Number 1	2	3	4	5	6	7	8	9	10
1	300	528	300	480	372	360	372	276	360	348
2	420	552	372	396	348	312	384	276	420	360
3	384	438	348	348	336	420	324	216	336	348
4	312	420	336	300	342	432	360	276	504	336
5	276	360	288	300	360	420	396	240	336	336
6	408	336	288	360	408	336	300	264	408	336
7	336	300	264	384	384	324	360	348	348	348
8	300	396	348	396	336	348	396	324	300	312
9	300	432	360	396	336	360	396	336	396	312
10	324	372	444	312	336	336	408	348	360	276
11	288	336	324	312	396	324	324	324	348	264
12	384	348	408	432	408	372	372	264	372	312
13	372	348	420	456	372	384	336	264	384	312
14	288	312	408	408	348	396	396	288	372	288
15	384	288	420	336	312	300	384	408	396	252
16	372	360	384	312	324	348	348	432	360	360
17	288	336	348	228	348	384	324	408	372	336
18	360	348	348	240	396	384	288	324	348	420
19	348	336	456	300	372	348	360	252	408	348
20	384	348	540	324	348	384	276	264	324	240

Average = 352.53

Standard Deviation = 54.54

Coefficient of Variation = 15.5%

Table 19. Breaking Strength in Grams From Autograph for 24's Cotton Yarn

Break Number	Bobbin Number 1	2	3	4	5	6	7	8	9	10
1	312	264	264	324	336	282	312	264	324	366
2	270	264	426	312	330	336	324	348	300	318
3	300	300	312	330	372	270	210	240	300	324
4	252	306	330	276	318	288	264	216	132	330
5	282	336	276	228	348	228	240	258	300	312
6	270	372	282	270	420	258	222	282	300	312
7	240	372	288	216	348	300	240	306	252	300
8	300	276	252	216	306	270	252	276	228	300
9	270	306	282	210	360	252	288	296	252	336
10	360	312	378	234	282	264	300	354	252	372
11	336	324	270	252	300	282	204	336	336	240
12	324	276	300	330	336	336	186	336	372	252
13	348	342	270	348	282	330	168	288	318	174
14	372	366	336	354	216	300	246	312	372	252
15	252	360	336	366	234	324	198	324	348	330
16	258	312	258	330	246	276	180	300	342	360
17	270	384	288	306	276	282	216	324	270	270
18	276	390	312	300	312	228	252	348	306	306
19	252	288	288	300	324	348	258	360	324	300
20	276	372	330	300	330	306	270	270	396	228

Average = 295.92

Standard Deviation = 49.74

Coefficient of Variation = 16.8%

Table 20. Breaking Strength in Grams From Autograph for 28's Cotton Yarn

Break Number	Bobbin Number 1	2	3	4	5	6	7	8	9	10
1	204	192	216	288	252	252	252	360	228	312
2	216	264	264	288	240	276	264	288	216	318
3	228	264	324	270	222	324	258	306	264	336
4	216	348	192	240	228	264	276	300	288	282
5	252	288	330	288	252	264	264	306	348	300
6	264	270	408	288	246	276	276	294	360	264
7	228	300	420	312	252	312	288	276	306	228
8	288	294	354	264	228	258	288	372	276	276
9	288	312	408	324	288	306	282	264	288	276
10	228	264	378	252	336	324	288	300	282	288
11	264	228	222	270	228	342	324	264	264	300
12	270	246	192	270	312	336	336	270	264	282
13	276	192	276	276	300	336	324	288	282	252
14	366	228	348	264	258	312	330	252	288	270
15	384	324	306	288	246	276	324	252	252	216
16	426	300	288	264	252	258	330	246	252	240
17	372	270	240	252	204	216	282	288	198	222
18	282	270	228	288	228	228	246	252	198	252
19	240	252	276	240	258	162	282	210	168	252
20	228	228	288	252	222	192	312	192	228	258

Average = 274.38

Standard Deviation = 46.33

Coefficient of Variation = 16.9%

Table 21. Per Cent Elongation at Breakage From Autograph for 20's Cotton Yarn.

Break	Bobbin Number									
Number	1	2	3	4	5	6	7	8	9	10
1	6.0	10.8	7.0	7.0	7.2	6.8	7.6	6.0	8.0	6.6
2	8.0	9.0	7.0	7.2	7.2	8.4	6.4	4.6	7.8	6.6
3	8.9	8.8	7.4	7.0	7.0	7.2	7.8	6.4	8.8	7.0
4	7.0	7.2	7.4	7.0	7.8	8.4	7.8	5.8	8.4	7.0
5	6.4	6.8	6.4	8.0	8.0	6.8	7.0	6.8	9.0	7.0
6	8.0	6.8	6.4	8.2	7.7	7.0	8.0	7.8	10.0	6.5
7	7.4	8.0	7.2	8.0	8.0	7.2	8.8	7.6	7.6	7.9
8	10.0	8.4	7.4	8.0	7.9	7.9	8.4	7.6	8.4	6.5
9	9.0	7.8	8.2	6.8	8.0	7.9	8.4	8.4	9.2	8.4
10	7.6	7.8	7.2	7.8	7.0	7.4	7.2	10.0	8.9	6.8
11	7.0	8.0	8.0	8.0	8.0	8.8	8.0	6.8	7.7	6.4
12	7.0	7.8	11.8	8.8	7.2	8.0	7.9	7.0	7.9	7.6
13	7.0	7.8	7.8	9.0	7.8	9.0	8.8	7.2	7.4	7.8
14	6.8	6.8	8.4	8.0	7.6	7.0	8.8	8.4	9.0	7.0
15	8.0	7.8	7.8	7.8	7.6	7.2	8.6	8.0	6.8	6.4
16	8.0	7.8	7.8	6.0	7.8	7.7	7.2	8.8	7.2	8.4
17	8.0	7.6	6.8	7.0	8.8	8.0	7.0	7.8	6.8	8.0
18	8.0	6.8	8.0	6.8	8.8	7.0	7.2	7.0	7.9	8.8
19	9.0	6.8	8.8	7.2	6.8	7.8	6.0	6.0	6.4	9.0
20	10.0	6.2	8.4	6.0	7.2	7.6	6.0	7.0	6.6	7.8

Average = 7.63

Standard Deviation = 0.937

Coefficient of Variation = 12.3%

Table 22. Per Cent Elongation at Breakage From Autograph for 24's Cotton Yarn

Break Number	Bobbin Number									
	1	2	3	4	5	6	7	8	9	10
1	7.0	7.0	7.8	8.0	7.0	7.8	8.0	6.6	7.4	9.8
2	6.8	6.8	9.8	9.8	7.8	8.0	8.8	9.0	7.8	6.8
3	7.0	8.0	8.4	9.6	9.9	8.0	6.8	8.0	8.4	8.0
4	6.0	8.2	8.0	7.8	7.4	8.6	7.0	6.0	7.2	9.0
5	7.0	7.8	7.6	6.8	7.4	6.8	6.4	6.6	7.0	7.0
6	6.8	8.2	6.4	6.8	9.6	7.0	5.0	6.6	6.8	6.8
7	6.0	8.2	6.8	5.0	7.8	6.4	5.4	6.2	6.0	6.4
8	7.4	6.0	5.8	4.8	6.8	6.4	5.8	5.8	5.0	6.0
9	6.8	7.0	8.4	4.8	7.2	6.4	6.6	6.2	4.8	6.8
10	8.0	8.0	8.0	6.0	6.8	6.8	7.2	7.8	5.2	7.8
11	7.8	7.8	6.6	5.8	7.4	7.0	5.4	8.4	7.8	6.6
12	7.0	6.8	7.0	7.9	7.8	7.0	4.4	7.2	7.6	6.2
13	7.8	7.2	5.4	7.2	7.4	6.0	4.0	6.4	6.4	6.4
14	7.8	8.0	6.6	7.2	5.0	6.0	5.0	6.4	7.0	7.0
15	5.0	7.2	6.6	7.2	5.0	6.8	5.4	6.0	6.8	8.0
16	6.0	6.4	5.8	7.6	5.8	6.4	4.8	6.3	7.8	7.9
17	6.0	8.6	6.6	7.0	6.6	7.2	5.8	6.8	5.6	5.8
18	7.2	8.6	7.0	7.6	7.2	5.8	6.4	7.0	6.8	7.0
19	6.4	7.8	6.6	6.8	8.0	7.9	6.4	8.0	7.8	6.8
20	7.0	9.0	7.6	6.8	7.6	7.9	7.2	7.0	9.0	6.0

Average = 6.99

Standard Deviation = 1.079

Coefficient of Variation = 15.4%

Table 23. Per Cent Elongation at Breakage From Autograph for 28's Cotton Yarn

Break Number	Bobbin Number 1	2	3	4	5	6	7	8	9	10
1	5.2	5.2	5.6	7.0	5.2	5.0	4.6	7.0	4.4	4.4
2	5.7	6.2	6.2	5.6	5.6	5.6	5.6	8.0	5.2	4.4
3	6.0	6.6	7.6	6.2	5.0	6.2	5.6	6.6	4.4	3.6
4	5.7	8.0	6.0	6.0	5.0	7.0	6.0	6.8	6.0	5.2
5	5.7	6.6	8.0	6.8	5.6	6.0	6.2	6.4	6.2	7.0
6	5.7	8.0	8.6	6.8	5.4	6.0	5.8	6.4	7.2	7.0
7	5.7	7.6	9.2	7.6	5.6	6.0	6.2	6.4	8.0	7.6
8	6.8	7.0	8.6	6.4	5.4	7.0	6.6	6.2	7.4	6.2
9	6.8	6.6	10.0	7.6	6.6	6.0	6.6	8.2	4.2	7.0
10	6.0	6.6	10.0	5.2	5.2	7.0	5.8	5.8	7.0	5.8
11	6.2	6.2	6.2	5.6	5.2	7.2	6.2	6.6	5.6	5.8
12	6.2	6.0	5.2	6.4	6.0	7.8	7.2	6.0	6.0	6.2
13	6.8	5.0	7.0	6.4	7.0	7.8	7.6	6.0	6.4	6.2
14	7.6	4.4	8.4	5.8	6.7	7.8	7.0	6.2	6.2	7.0
15	8.6	7.0	7.4	6.2	5.6	7.0	7.2	5.6	5.8	7.0
16	8.7	7.0	7.2	6.0	5.4	6.6	7.2	5.6	6.0	6.2
17	7.6	6.2	5.6	5.2	6.0	6.0	7.4	5.8	6.2	5.8
18	7.0	6.6	5.6	6.6	4.6	4.6	6.8	6.6	6.6	6.0
19	5.2	7.0	6.4	5.2	4.8	5.0	5.8	5.8	5.8	5.0
20	5.2	7.2	6.6	5.6	6.0	3.6	6.2	5.0	5.8	7.0

Average = 6.32

Standard Deviation = 1.036

Coefficient of Variation = 16.4%

Table 24. Per Cent Coefficient of Variation for the Evenness of Products

Sample Number	Test Number	Card Sliver	Drawing Sliver	Roving	20's Yarn	24's Yarn	28's Yarn
1	1	4.15	3.35	5.19	20.10	21.00	20.80
	2	3.90	3.40	6.00	20.15	21.60	20.75
	3	3.88	3.70	5.25	20.50	21.55	19.65
	4	3.75	3.80	5.50	20.25	21.45	19.75
	5	4.05	3.45	5.65	20.40	21.05	20.45
2	1	3.75	3.48	5.85	20.10	21.50	20.65
	2	3.68	3.40	5.90	19.95	21.55	20.45
	3	3.58	3.60	5.65	19.90	21.40	20.50
	4	3.70	3.75	5.07	20.05	21.40	19.80
	5	3.73	3.42	5.75	20.45	20.90	19.45
3	1	4.10	3.28	6.10	20.45	21.65	19.50
	2	4.15	3.28	6.05	20.05	20.80	19.45
	3	4.10	3.32	5.59	20.00	20.75	20.25
	4	4.05	3.40	5.87	20.35	20.65	19.35
	5	3.95	3.48	6.00	20.40	21.10	20.75
4	1	3.24	3.49	6.15	19.75	21.00	20.30
	2	3.38	3.57	6.25	19.95	21.00	20.10
	3	3.35	3.50	5.65	19.90	20.95	20.50
	4	3.40	3.40	6.15	19.90	20.65	20.50
	5	3.70	3.62	5.92	20.10	20.80	20.30
Average		3.732	3.485	5.777	20.135	21.138	20.163

Table 25. End Breakage Test Summary Sheet for 20's Yarn, Test Number 1

Time Interval	Breaks	Breaks per 1000 Spindle Hours	Lashes	Roving Breaks	Traveller Off	Hard End	Thin Place	Roller Lap	Total	Total per 1000 Spindle Hours	Initial Roving Bobbin Size 1/3 F.	2/3 F.	Full
04:00-04:15 pm	5	120		2					7	168	4	2	1
04:15-04:30	5	120			1				6	144	2	1	3
04:30-04:45	2	48	2				2		6	144	2	2	2
04:45-05:00	5	120		1					6	144	3	1	2
05:00-05:15	3	72							3	72	0	2	1
05:15-05:30	1	24					1		2	48	0	2	0
05:30-05:45	4	96							4	96	1	2	1
05:45-06:00	1	24							1	24	0	1	0
06:00-06:15	2	48							2	48	1	0	1
06:15-06:30	1	24		2		1	1		5	120	5	0	0
06:30-06:45	3	72				1	1	1	6	144	1	1	4
06:45-07:00	3	72							3	72	1	0	2
07:00-07:15	2	48					1		3	72	0	1	2
07:15-07:30	3	72							3	72	2	0	1
07:30-07:45	1	24							1	24	0	1	0
07:45-08:00	3	72							3	72	2	1	0
08:00-08:15	3	72							3	72	2	0	1
08:15-08:30	3	72		1			1		5	120	4	0	1
08:30-08:45	3	72			1	1			5	120	1	1	3
08:15-08:30 am	1	24							1	24	0	1	0
08:30-08:45	1	24							1	24	0	0	1
08:45-09:00	2	48							2	48	1	0	1

Total Spindle Hours = 924

Table 26. End Breakage Test Summary Sheet for 20's Yarn, Test Number 2

Time Interval	Breaks	Breaks per 1000 Spindle Hours	Lashes	Roving Breaks	Traveller Off	Hard End	Thin Place	Roller Lap	Total	Total per 1000 Spindle Hours	Initial Roving Bobbin Size: 1/3 F.	Initial Roving Bobbin Size: 2/3 F.	Initial Roving Bobbin Size: Full
10:15-10:30 am	6	144							6	144	2	1	3
10:30-10:45	3	72							3	72	0	1	[illegible]
10:45-11:00	1	24							1	24	0	0	1
11:00-11:15	2	48							2	48	1	1	0
11:15-11:30	1	24	1	2					4	96	3	0	1
11:30-11:45	3	72				2	1		6	144	5	0	1
11:45-12:00	2	48		1					3	73	2	0	1
01:15-01:30 pm	4	96				1			5	120	3	1	1
01:30-01:45	2	48	1						3	72	1	1	1
01:45-02:00	3	72					1		4	96	0	1	3
02:00-02:15	3	72							3	72	1	1	1
02:15-02:30	1	24							1	24	1	0	0
02:30-02:45	1	24							1	24	0	1	0
06:45-07:00 pm	3	72	1						4	96	1	2	1
07:00-07:15	3	72		1					4	96	2	1	1
07:15-07:30	1	24				1			2	48	1	0	1
07:30-07:45	4	96							4	96	1	1	2
07:45-08:00	2	48							2	48	0	0	2
08:00-08:15	2	48							2	48	1	1	0
08:15-08:30	0	00		1					1	24	0	0	1
08:30-08:45	4	96							4	96	2	1	1
08:45-09:00	2	48		1					3	72	2	0	1
09:00-09:15	1	24		1		1			3	72	1	1	1

Total Spindle Hours = 966

Table 27. End Breakage Test Summary Sheet for 24's Yarn, Test Number 1

Time Interval	Breaks	Breaks per 1000 Spindle Hours	Lashes	Roving Breaks	Traveller Off	Hard End	Thin Place	Roller Lap	Total	Total per 1000 Spindle Hours	Initial Roving Bobbin Size 1/3 F.	Initial Roving Bobbin Size 2/3 F.	Initial Roving Bobbin Size Full
08:45-09:00 am	6	144	1	1		1			9	216	4	3	2
09:00-09:15	2	48							2	48	0	1	1
09:15-09:30	2	48		1			1		3	72	0	2	1
09:30-09:45	3	72		1					4	96	1	2	1
09:45-10:00	3	72							3	72	2	0	1
10:00-10:15	1	24							1	24	0	0	1
10:15-10:30	3	72							3	72	1	2	0
10:30-10:45	2	48		1					3	72	1	1	1
10:45-11:00	3	72		1					4	96	1	3	0
11:00-11:15	5	120						1	6	144	3	1	2
11:15-11:30	3	72							3	72	1	1	1
01:15-01:30 pm	3	72							3	72	1	1	1
01:30-01:45	2	48							2	48	0	1	1
01:45-02:00	3	72							3	72	2	1	0
02:00-02:15	2	48	1	1					4	96	2	1	1
02:15-02:30	0	0							0	0	0	0	0
02:30-02:45	2	48							2	48	0	1	1
02:45-03:00	1	24							1	24	0	0	1
03:00-03:15	1	24							1	24	0	1	0
03:15-03:30	2	48							2	48	0	2	0
03:30-03:45	1	24					1		2	48	1	1	0
03:45-04:00	3	72							3	72	1	2	0
04:00-04:15	3	72							3	72	1	2	0
09:30-09:45 am	2	48							2	48	2	0	0
09:45-10:00	2	48							2	48	0	1	1
10:00-10:15	4	96							4	96	1	3	0
10:15-10:30	1	24							1	24	0	1	0
10:30-10:45	4	96							4	96	0	1	3
10:45-11:00	3	72							3	72	2	1	0
11:00-11:15	2	48							2	48	2	0	0
11:15-11:30	3	72				1			4	96	0	2	2
11:30-11:45	2	48							2	48	0	0	2
11:45-12:00	3	72							3	72	3	0	0
12:00-12:15	5	120							5	120	2	2	1

Total Spindle Hours = 1428

Table 28. End Breakage Test Summary Sheet for 24's Yarn, Test Number 2

Time Interval	Breaks	Breaks per 1000 Spindle Hours	Lashes	Roving Breaks	Traveller Off	Hard End	Thin Place	Roller Lap	Total	Total per 1000 Spindle Hours	Initial Roving Bobbin Size 1/3 F.	2/3 F.	Full
11:30-11:45 am	7	168							7	168	2	2	3
11:45-12:00	4	96							4	96	3	0	1
05:15-05:30 pm	3	72							3	72	0	2	1
05:30-05:45	1	24							1	24	0	0	1
05:45-06:00	3	72							3	72	1	0	2
06:00-06:15	3	72							3	72	2	0	1
06:15-06:30	2	48							2	48	0	1	1
06:30-06:45	2	48					1		3	72	2	0	1
06:45-07:00	2	48							2	48	0	1	1
07:00-07:15	3	72							3	72	1	0	2
07:15-07:30	3	72		1		1			5	120	1	3	1
07:30-07:45	3	72				1			4	96	2	1	1
07:45-08:00	2	48							2	48	0	0	2
03:30-03:45	1	24							1	24	0	0	1
03:45-04:00	3	72							3	72	1	1	1
04:00-04:15	3	72							3	72	1	1	1
04:15-04:30	2	48							2	48	0	1	1
04:30-04:45	2	48							2	48	1	0	1
04:45-05:00	1	24							1	24	1	0	0
05:00-05:15	2	48							2	48	0	2	0
05:15-05:30	2	48				1			3	72	0	3	0
05:30-05:45	1	24							1	24	1	0	0
05:45-06:00	2	48							2	48	1	1	0
06:00-06:15	5	120							5	120	4	1	0
06:15-06:30	4	96		1			1		6	144	3	2	1
06:30-06:45	5	120		1		1		1	8	192	5	1	2
06:45-07:00	5	120							5	120	3	0	2
07:00-07:15	5	120							5	120	1	3	1
07:15-07:30	4	96							4	96	3	0	1
07:30-07:45	4	96							4	96	3	0	1
07:45-08:00	4	96							4	96	1	0	3
08:00-08:15	3	72							3	72	2	0	1
08:15-08:30	3	72							3	72	3	0	0

Total Spindle Hours = 1386

Table 29. End Breakage Test Summary Sheet for 28's Yarn, Test Number 1

Time Interval	Breaks	Breaks per 1000 Spindle Hours	Lashes	Roving Breaks	Traveller Off	Hard End	Thin Place	Roller Lap	Total	Total per 1000 Spindle Hours	Initial Roving Bobbin Size: 1/3 F.	Initial Roving Bobbin Size: 2/3 F.	Initial Roving Bobbin Size: Full
03:15-03:30 pm	2	288				1			13	312	5	3	5
03:30-03:45	10	240							10	240	3	2	5
03:45-04:00	8	192							8	192	5	1	2
04:00-04:15	6	144				1			7	168	4	0	3
04:15-04:30	6	144					1		7	168	5	1	1
04:30-04:45	6	144	1				2		9	216	5	2	2
04:45-05:00	6	144							6	144	2	1	3
05:00-05:15	4	96							4	96	3	0	1
05:15-05:30	5	120				1	1		7	168	5	0	2
05:30-05:45	7	168					1		8	192	3	1	4
05:45-06:00	5	120					1		6	144	2	0	4
06:00-06:15	4	96				1	1		6	144	1	1	4
06:15-06:30	7	168							7	168	3	1	3
06:30-06:45	6	144					2		8	192	5	1	2
06:45-07:00	10	240							10	240	5	1	4
07:00-07:15	5	120					1		6	144	5	0	1
07:15-07:30	7	168							7	168	4	2	1
07:30-07:45	6	144					1		7	168	3	4	0
09:30-09:45 am	6	144							6	144	2	3	1
09:45-10:00	8	192				2	1		11	264	5	4	2
10:00-10:15	5	120				1			6	144	3	1	2
10:15-10:30	6	144				1			7	168	1	3	3
10:30-10:45	6	144				1			7	168	1	2	4
10:45-11:00	9	216				1			10	240	5	2	3
11:00-11:15	10	240							10	240	8	1	1
11:15-11:30	10	240					1		11	264	7	2	2
11:30-11:45	13	312							13	312	6	3	4

Total Spindle Hours = 1134

Table 30. End Breakage Test Summary Sheet for 28's Yarn, Test Number 2

Time Interval	Breaks	Breaks per 1000 Spindle Hours	Lashes	Roving Breaks	Traveller Off	Hard End	Thin Place	Roller Lap	Total	Total per 1000 Spindle Hours	Initial Roving Bobbin Size 1/3 F.	2/3 F.	Full
02:00-02:15 pm	10	240				1	1		12	288	1	3	8
02:15-02:30	9	216	1			1			11	264	1	3	7
02:30-02:45	6	144							6	144	1	2	3
02:45-03:00	6	144	1						7	168	4	1	3
03:00-03:15	7	168				1			8	192	0	3	5
03:15-03:30	6	144						1	7	168	1	3	3
03:30-03:45	6	144				1			7	168	0	1	6
03.45-04:00	4	96			1	1			6	144	2	2	2
04:00-04:15	5	120							5	120	1	0	4
04:15-04:30	3	72							3	72	0	1	2
04:30-04:45	5	120							5	120	2	2	1
04:45-05:00	7	168		1					8	192	0	6	2
05:00-05:15	5	120					1		6	144	0	4	2
05:15-05:30	6	144							6	144	2	2	2
05:30-05:45	5	120							5	120	3	1	1
05.45-06:00	6	144		1		1			8	192	3	0	5
06:00-06:15	6	144					1		7	168	4	1	2
06:15-06:30	6	144							6	144	3	0	3
06:30-06:45	7	168				1	1		9	216	6	2	1
06:45-07:00	4	96	1						5	120	1	2	2
07:00-07:15	7	168							7	168	3	1	3
07.15-07:30	6	144				1			7	168	4	1	2
07:30-07:45	7	168				1	1		9	216	3	3	3
07:45-08:00	10	240		1			1		12	288	7	2	3
08:00-08:15	9	216				1			10	240	6	2	2
08:15-08:30	10	240	1						11	264	1	4	6
08:30-08:45	11	264	1						12	288	10	1	1
08:45-09:00	12	288	1						13	312	7	2	4

Total Spindle Hours = 1176

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